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Date: 1-November-2011

Knowledge Transfer Mechanisms of University-Industry Collaboration: An Empirical Analysis of the Biotechnology Industry

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Doctor of Philosophy
The University of Edinburgh
2011

Abstract

This study aims to adopt the transaction cost economics, resource-based theory, and social exchange theory to theoretically analyse university-industry knowledge transfer activities and their determinants and consequences. Four mechanisms are identified for university-industry knowledge transfer, namely equity-based transfer, research contract-based transfer, general contract-based transfer, and relation-based transfer. These determinants are examined in three categories, namely, resource factors, resource dependency and complementarities, and transaction cost factors. The sample was gathered from 145 Taiwanese biotechnology firms, and the results indicate that collaboration with a university improves a firm's knowledge transfer performance in terms of knowledge acquisition, knowledge generation, and commercial success. Relation-based transfer and general contract-based transfer are the most effective ways in which to transfer knowledge, and these are followed by research contract-based transfer, and equity-based transfer respectively. Furthermore, the empirical results illustrate that not all types of resources contribute to university-industry knowledge transfer activities and knowledge transfer performance. A firm's resources are found to be useful for the formation of collaboration, and a university's resources are beneficial for improving knowledge transfer performance, particularly when they have more knowledge resources and organisational resources. Technology transfer office resources and the relationship resources of universities and firms facilitate an equity-based transfer and improve the performance of knowledge transfer. However, the greater property-based resources of a university and a firm do not generate more university-industry knowledge transfer activities and a better knowledge transfer performance. A university's greater property-based resources can even decrease the knowledge transfer performance. In addition, it was found that knowledge asset specificity and market uncertainty are related to the formation of a relation-based transfer, general contract-based transfer, and research contract-based transfer. However, resource dependency and resource complementarity do not appear to have an effect on facilitating university-industry knowledge transfer activities and knowledge transfer performance.

Preface

With the increasingly rapid changes in the development of technology, the role played by university-industry collaboration in shaping the innovative performances of universities and firms has been a key issue in the recent debate. Although the researchers have made progress in understanding the motivations and determinants of university-industry collaborations, most of the studies focused on university spin-offs. In addition, more current studies usually provided a partial glimpse into the set of factors which may operate at the university-industry collaborations, and resources of firms and universities have usually been examined independently of each other. It still lacks systematical and theoretical analyses to explore UIC. According to the research gaps of existing studies, this thesis attempts to examine university-industry knowledge transfer with the related theoretical paradigms, including resource-based theory, transaction cost economics, resource dependency theory, and social exchange theory. Furthermore, we attempt to theoretically analyse the knowledge transfer activities of UIC, their determinants and knowledge performance. The thesis identifies ten university-industry knowledge transfer activities of UIC and classifies them into three mechanisms, namely equity-based transfer, contract-based transfer, and relational-based transfer. This thesis posits that the resource profile of universities and industry in terms of property-based resources, knowledge resources, relationship resources, organisational resources and technology transfer office resources all contribute to influencing university-industry knowledge transfer mechanisms and a firm's knowledge transfer performance, such as knowledge acquisition, knowledge creation, and the commercial success of firms. Furthermore, this study also attempts to examine the role of resource dependency, resource complementarity, and transaction factors such as asset specificity and uncertainty of university-industry knowledge transfer mechanisms and knowledge transfer performance. This study uses a sample of biotechnology firms because universities and research institutes are particularly the primary source of basic science research for the biotechnology industry to discover the potential commercial value of academic research. The framework and empirical results can provide a starting point to bring universities and business closer together, and enable them to transfer knowledge more efficiently.

Acknowledgements

I would like to take this opportunity to offer my great gratitude to a number of people without whose help and support this thesis would never have been possible.

First and foremost I offer my sincerest gratitude to my supervisor, Professor John Dawson, who has supported me thoughout my thesis with his patience and knowledge whilst allowing me to work in my way. I thank him so much for his continuous understanding, encouragements, and precious advice.

I would like to thank my internal examiner Prof Jake Ansell and external examiner Prof Marta Frasquet for the advices and guidance and being such a nice and supportive teacher and friend to me.

I cannot end without thanking my parents, on whose encouragement and support I have relied throughout my time at the Academy.

Lastly, I would like to specially give my immense pleasure to thank my beloved husband, Nien-Jen, who always gives me the solid support, concern, and endless love. I dedicate the work to him and my family.

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Chapter 1 Introduction

1.1 Research Background

A great deal of theoretical and empirical research has been dedicated to understanding technological alliances and R&D cooperation, and evidence that external R&D cooperation is beneficial to a firm's innovation performance has been found in several cross-sectional studies (e.g. Lööf and Broström, 2008; Aschhoff and Schmidt, 2008, Lööf and Heshmati, 2002; Miotti and Sachwald, 2003; Cincera et al., 2003; Belderbos et al., 2004; Lhuillery and Pfister, 2009). Technology and R&D alliances are formed with suppliers, customers, competitors, universities, and research institutes. Technology and R&D alliances include various forms of collaborative agreements, such as outsourcing, joint research and development projects, joint manufacturing, joint distribution, joint ventures, franchising, etc. (Yoshino and Rangan, 1995; Johansson, 2008).

With the increasingly rapid changes in the development of technology, the role played by university-industry collaboration (UIC) in shaping the innovative performances of universities and firms has been a key issue in the recent debate on the determinants of innovation (Bonaccorsi and Piccaluga, 1994; Agrawal and Henderson, 2002; Cohen et al., 2002; Feldman et al., 2002; Murmann, 2003; Baba et al., 2009). A variety of issues are involved in university-industry collaborations, and early research focused on the motivations and obstacles of forming a collaboration. In past decades, many studies explored the channels and drivers of collaboration, and as the importance of knowledge management increased, a growing number of studies highlighted the transfer of knowledge between university and industry. In summary, UIC literature can be classified into the following four main areas: (1) interactive channels of collaboration, (2) knowledge transfer of collaboration, (3) input factors which influence collaboration, (4) output performance of collaboration.

- **Interactive Channels of University-Industry Collaborations**

Some researchers have focused on one specific form of university-industry collaboration and explored its foundation and determinants. University-industry spin-off activities have also received a great deal of attention (e.g.: O'Shea et al., 2007; Wright et al., 2006; Landry et al., 2006; Agrawal, 2006; Rothaermel and Thursby, 2005; Lockett and Wright, 2005; Leitch and Harrison, 2005; O'Shea et al., 2005; Vohora et al., 2004; Nicolaou and Birley, 2003; Di Gregorio and Shane, 2003; Zucker et al., 1998; Acs et al., 1996), followed by university-industry licensing activities (e.g.; Yusuf, 2008; Shane and Somaya, 2007; Woolgar, 2007; Macho-Stadler et al., 2007; Geuna and Nesta, 2006; Horng and Hsueh, 2005), R&D research projects (D'Este and Patel), academic consultations (Perkmann and Walsh, 2008) and individual informal contacts (Østergaard, 2008; Boardman, 2008).

On the other hand, several researchers have examined a variety of university-industry collaborative forms. For example, D'Este and Patel (2007) explored the difference between the individual and departmental characteristics of academic researchers who are engaged in meetings and conferences, consultancy and contract research, the creation of physical facilities, training, and joint research with industry. Wright et al. (2008) investigated the way in which EU mid-range universities contribute to industrial change through knowledge transfer activities, such as licensing, patents, consultancy, spin-offs, contract research, and graduate and researcher mobility, whereas Cohen et al. (1998), Arvanitis et al. (2008), and Bekkers and Bodas Freitas (2008) examined university-industry knowledge and technology transfer activities. However, these studies did not explore the determinants and consequences of these knowledge transfer activities.

- **Knowledge Transfer of University-Industry Collaborations**

A second group of studies focused on knowledge spillovers and knowledge transfers, particularly scientific knowledge from university to industry (e.g. Welsh et al., 2008; Stuart et al., 2007; Siegel et al., 2003). Lam (2007) indicated that particularly high-technology industries have to break through the limitations of internal R&D by becoming involved in external collaborative projects to gain access to the knowledge of university researchers. Several studies showed evidence of a trend of knowledge flow from universities to firms by analysing the patenting, patenting citation, publication, and publication citation of academic research (e.g. Rosell and Agrawal, 2009; Baldini et al., 2006). Related knowledge topics include knowledge integration community (Acworth, 2008), effective knowledge transfer (Yusuf, 2008), UC Berkeley's knowledge transfer Paradigm (Burnside and Witkin, 2008), geographical constraints on knowledge transfer (Hong, 2008), and the effectiveness of knowledge transfer (Siegel et al., 2004; Anderson et al., 2007).

- **Determinants of University-Industry Collaborations**

The third group of studies, which accounted for a large number of articles, attempted to identify the industry and university characteristics and factors which affect the way in which a UIC is formed (e.g. Cohen et al., 2002; Bruno and Orsenigo, 2003; Fontana et al., 2006; Arundel and Geuna, 2004; Yusuf, 2008; Boardman and Corley, 2008; Segarra-Blasco and Arauzo-Carod, 2008; Sherwood and Covin, 2008; Hussler and Rondé, 2007; Azagra-Caro et al., 2006; Mueller, 2006; Veugelers and Cassiman, 2005; Laursen and Salter, 2004; Fischer and Varga, 2003; Giuliani and Arzab, 2009). These studies tended to explore the determining factors of firms' characteristics, universities' characteristics, and their relationship and networking. Firms' characteristics included their knowledge base (Giuliani and Arza, 2009), their size and the intensity of their R&D, (Segarra-Blasco and Arauzo-Carod, 2008; Laursen and Salter, 2004), their age (Laursen and Salter, 2004), intramural R&D activities (Segarra-Blasco and Arauzo-Carod, 2008), experience of technological agreements (Sherwood and Covin, 2008), their R&D in private industries (Mueller, 2006), and corporate R&D investment (Fischer and Varga, 2003). Universities' characteristics included the scientific quality of their departments (Giuliani and Arza, 2009), university encouragement and the age of the university involved (Azagra-Caro et al., 2006), R&D in universities (Mueller, 2006), universities' R&D investment (Fischer and Varga, 2003), industrial grants per university researcher (Mueller, 2006), faculty support (Azagra-Caro et al., 2006), orientation to applied research, teaching obligations, and experience of industry cooperation (Arvanitis et al., 2008), and universities' rewards of technology transfer and marketing experience and skills (Horng and Hsueh, 2005). Some researchers have argued that social factors are useful for the creation of UIC. These social factors include (McAdam et al., 2006), university network with industry (Segarra-Blasco and Arauzo-Carod, 2008), industry network with academia (Stuart et al., 2007), embeddedness in industry networks (Owen-Smith and Powell, 2003), trust and commitment (Thune, 2007; Plewa and Quester, 2007; Philbin, 2008), communication, trust and familiarity with the partner (Sherwood and Covin, 2008).

- **Consequence of University-Industry Collaboration**

The final group of studies was dedicated to the consequences of UIC. Empirical studies demonstrate that UIC are beneficial for both universities and industry. For universities, collaboration with industry was found to increase university researchers' publications (Abramo et al., 2009), patent citations (Owen-Smith and Powell, 2003), licensing (Horng and Hsueh, 2005), patent grants and licensing income (Chang et al., 2006), licensing and spin-offs (Arvanitis et al., 2008). For industry, academic knowledge is a critical external source for a firm's innovation activities (Griliches, 1990; Nonaka and Takeuchi, 1995, Jiang and Li, 2009). Collaboration with an academic institution has been found to have a positive influence on a firm's innovation performance, such as the development of new technology and processes (Mansfield, 1995), patents (Adams et al., 2001; Miotti and Sachwald, 2003; Fischer and Varga, 2003; Brennan, 2003; Lööf and Broström, 2008; Foltz et al., 2003), patent application (Baba et al., 2009), new product development (Aschhoff and Schmidt, 2008; Brennan, 2003), innovative sales (Belderbos et al., 2004), and the sale of new products (Lööf and Broström, 2008). For industries involved in fast developing technologies like biotechnology, information technology and new materials, scientific knowledge is especially important for innovation (Cockburn and Henderson, 1996; Zucker et al., 1998; Veugelers and Cassiman, 2005).

1.2 Research Motivation and Research Objectives

Although researchers have made progress in understanding the motivation, determinants, formation, the consequences of UIC, prior literature still has some limitations, the first of which is that earlier studies usually focused on specific collaborative forms and explored their determinants and impacts, such as spin-offs and licensing, which are of the most interest. Some studies attempted to understand comprehensive university-industry collaborative activities by mainly assessing their relative importance, but lacked systematic and theoretical analyses to explore the impact of different channels.

Secondly, more current studies usually provided a partial glimpse into the set of factors which may operate in a UIC (Sherwood and Covin, 2008), but these have generally not been explored within a theoretical framework. Moreover, resource stocks, such as the R&D expenditure and R&D faults of firms and universities, do not match what they would contribute in collaboration, and this may bias the results.

Thirdly, the resources of firms and universities have usually been examined independently of each other. Only a few studies have investigated the resources input by both parties, and no research has investigated the impact of a resource gap between firms and universities on their collaboration. From a strategic alliance perspective, a firm which gains access to complementary resources by linking to a partner can create a synergy between resources. However, current studies barely show evidence of the impact of sharing resources between university and industry.

Fourthly, transaction cost economics has been applied to understand the transaction costs arising from an alliance to protect against a partner's opportunistic behaviour. There are still very few studies which use transaction cost economics to examine university-industry collaboration.

Fifthly, codified variables such as patents and patent citations seem to be the most widely-used indicators of outputs of industrial innovation. Codified data has the advantage of being simple, objective, and accessible from archived data. However, codified data has several limitations. These variables only present a partial aspect of innovation, and codified productivities are unable to confirm the overall commercial success of innovation. Moreover, a greater number of codified innovation outputs may be caused by a firm's internal R&D efforts rather than collaboration.

Finally, over the past years, research regarding UIC has concentrated on the determinants of formation, the forms of interaction, and the impact on firm/university performance. However, there is still a lack of studies analysing the relationship among internal firm resources, external university resources, knowledge transfer activities between university and industry, and their performance.

Technology alliance and R&D cooperation in an inter-firm context have been analysed with many theories to conceptualise and explain firms' structure and behaviour and to provide an explanation of the phenomena in traditional strategic literature (Grant, 1991). UIC are a specific form of technology alliance (Østergaard, 2008). However, there has been a lack of studies to investigate it with a theoretical framework. UIC are similar to the context of a firm's boundary, but not exactly equivalent. Based on the similarity of inter-organisational cooperation, alliance theories could be extended to UIC while considering the unique characteristics of universities and industry (Eun et al., 2006). For example, universities mainly play a role in providing general knowledge and scientific breakthroughs, while industry tends to provide applied research for economic profit. In contrast to "maximising the profits" of the business operation, university centres emphasise educating academic highly-skilled manpower and conducting fundamental research. Furthermore, equity ventures alliances in inter-firm conditions, such as mergers and acquisitions, could hardly be undertaken between universities and industry.

According to the research background and research gaps of existing studies, this study attempts to examine university-industry knowledge transfer with related theoretical paradigms, including the resource-based theory, transaction cost theory, resource dependency theory, and social exchange theory. Furthermore, it attempts to theoretically analyse the knowledge transfer activities of UIC, their determinants and knowledge performance.

This thesis aims to explore the following issues in subsequent chapters:

- **Identify knowledge transfer mechanisms and explore their impact on knowledge transfer performance.**

The study identifies ten university-industry knowledge transfer activities of UIC and explores their characteristics of knowledge transfer. Ten university-industry knowledge transfer activities include spin-offs, licensing, joint research, contract research, consultancy, training, research mobility, meetings and conferences, informal contacts, and co-authoring. A further ten knowledge transfer activities are classified into three university-industry knowledge transfer mechanisms, including equity-based transfer, contract-based transfer, and relation-based transfer. The relationship between three types of knowledge transfer mechanisms and a firm's knowledge transfer performance is also investigated.

- **Identify the innovation productivity of knowledge transfer activities between firms and universities**

This study differentiates the innovation productivity of knowledge transfer activities between firms and universities and focuses on the innovation productivity of firms, namely knowledge acquisition, knowledge creation, and commercial success.

- **Employ the resource-based theory and social exchange theory to identify the resource set of universities and firms respectively, and further explore their impact on university-industry knowledge transfer mechanisms and knowledge transfer performance**

Due to the lack of research into the resource determinants of university-industry knowledge transfers, academic efforts to address the resources which facilitate university-industry knowledge transfer are still inadequate. The resource-based theory is regarded as being a key theory to explain resources and competitiveness, and it is employed to explore the role played by resources in the transfer of university-industry knowledge. The resource-based theory assumes that the internal resources of a firm create its competitive advantage. This study argues that both the internal resources of the firm, and the external resources acquired from a partner, constitute the firm's competitive advantage. A further five groups of resources are identified according to their characteristics, namely, property-based resources, knowledge resources, relationship resources, organisational resources, and Technology Transfer Office resources.

- **Employ transaction cost economics to identify transaction cost factors and explore their impact on university-industry knowledge transfer mechanisms.**

The other influential theory is transaction cost economics. Assessing transactions costs is useful when making a decision about the governance structures of strategic alliances. Few UIC studies examine the transaction cost or governance mechanism of the collaboration between universities and industry. This thesis argues that the level of transaction cost caused by asset specificity and uncertainty may influence the transfer mechanism of university-industry knowledge.

- **Introduce the concept of resource complementarity and resource dependency in the context of university-industry knowledge transfer.**

This study is based on the assumption that each collaborative activity involves a profile of "give-and-take" of resources. To be more successful in creating inventions from the transfer of university-industry knowledge, firms have to adopt a combination of internal and external resources. This study seeks to determine how these resource profiles, offered by the focal firm and university partners, affect the means and outputs of knowledge transfer.

In summary, this study employs the resource-based theory, transaction cost economics, and the social exchange theory to explore the factors which influence the transfer of knowledge between universities and industry. Neither the resource-based theory nor transaction cost economics alone can fully explain the complexity of such a collaboration. This study identifies ten knowledge transfer activities and classifies them into three mechanisms, namely, equity-based, contract-based, and relation-based transfers. It is posited that the resource profile of universities and industry in terms of property-based resources, knowledge resources, relationship resources, organisational resources and Technology Transfer Office resources all contribute to influencing university-industry knowledge transfer mechanisms and a firm's knowledge transfer performance, such as knowledge acquisition, knowledge creation, and the commercial success of firms. Furthermore, this study also examines the role of resource dependency, resource complementarity, and transaction factors such as asset specificity and uncertainty of university-industry knowledge transfer mechanisms and knowledge transfer performance.

1.3 Organisation of the Dissertation

The chapters of this study are organised as follows:

Chapter 1 is an introduction to the thesis. The research objectives of the study are developed based on the research background and motivation.

Chapter 2 contains a literature review. This section begins with a discussion about motivation, benefits, barriers, development in Taiwan, and the innovative performance of university-industry knowledge transfer. The section also provides a theoretical background of the resource-based theory, transaction cost economics, and the social exchange theory in the UIC context. The resource factors and transaction factors which determine university-industry knowledge transfer and the dimensions of knowledge transfer performance are identified in this section.

Chapter 3 discusses university-industry knowledge transfer activities and develops a framework of university-industry knowledge transfer mechanisms.

Chapter 4 presents the research framework and explains the research hypotheses. A conceptual model is developed based on the literature review and research objectives. Hypotheses are developed in terms of the relationship among resource factors, transaction cost factors, resource dependency and complementarity, university-industry knowledge transfer mechanisms, and knowledge transfer performance.

Chapter 5 describes the methodology of this study, including the sample source and data collection, research design, and measurement development.

Chapter 6 presents the sample profile, factor analysis and reliability analysis, statistical analysis, and the results of the hypotheses.

Chapter 7 discusses the findings, conclusion, and limitations of this paper.

Chapter 2 Literature Review

The literature review consists of the following sections:

2.1: presents the motivations, benefits, and barriers of UIC. It also includes an introduction of the UIC development system in Taiwan.

2.2: refers to the relationship between UIC and innovation performance.

2.3: uses the resource-based theory and empirical studies to explore the resources of UIC.

2.4: discusses the resource factors in UIC.

2.5: employs transaction cost economics and empirical studies to explore the transaction factors, the resource complementarity, and the resource dependency of UIC.

2.6: applies the social exchange theory to discuss the relationship resources and relation–based transfer of UIC.

2.7: discusses the channels of university-industry interactions and collaboration.

2.1 University-Industry Collaboration

A growing number of studies have investigated the formation and initiation of interactions between academic institutes and industry (e.g. Arundel and Geuna, 2004; Bruno and Orsenigo, 2003; Cohen et al., 2002; Fontana et al., 2006; Di Gregorio and Shane, 2003; Hall et al., 2003; Link and Scott, 2003; Van Looy et al., 2004; Arvanitis et al., 2008). UIC is considered to be a crucial factor which contributes to a superior innovation performance, either at the firm-level, industry-level or country-level. This demonstrates its increasing impact on innovation productivity, particularly for technology-intensive industries (Arvanitis et al., 2008). Before the 1990s, UIC literature tended to attempt to understand the nature of tasks and motivations, policy, and the attitude of researchers toward collaboration (Geisler and Rubenstein, 1989).

However, in the last decade, many studies have been conducted in the search for collaboration and interaction between universities and industry, and these studies have created various terminologies in this topic, such as university–industry relationship (Perkmann and Walsh, 2009; Glenna et al., 2007; Azagra-Caro et al., 2006; Eun et al., 2006; Mueller, 2006), university–industry research relationship (Welsh et al., 2008), university–industry collaboration (Abramo et al., 2009;

Burnside and Witkin, 2008; Motohashi, 2005; Carrington et al., 2005; Siegel et al., 2003a, 2003b), university–industry knowledge and technology transfer (Arvanitis et al., 2008, Siegel et al., 2004), university–industry links (Østergaard, 2008; Tether and Tajar, 2008; Woolgar, 2007; Calantone and Stanko, 2007; Lam, 2007), university-industry linkages (Giuliani and Arza, 2009; Kodama, 2008; Wright, et al., 2008; D'Este and Patel, 2007; Hershberg et al., 2007; Doutriaux, 2003), university-industry interactions (Segarra-Blasco and Arauzo-Carod, 2008; Azagra-Caro, 2007; Smith and Bagchi-Sen, 2006), university-industry alliances (Sherwood and Covin, 2008), university–industry engagement (Acworth, 2008), triple helix model of government, university and industry (Etzkowitz and Leydesdorff, 2000; Marques et al., 2006), and university-run enterprises (Eun et al., 2006).

Although these authors discussed the UIC from various perspectives, covering the issues of motivation, formation, interaction types, determinants, knowledge transfer, and the performance of UIC, they all pointed to the trend of increasing interaction and collaboration between universities and industry. This interest in UIC has generated numerous works, which vary greatly in their level of analysis (e.g. regional, industry, university, government, and individual), structure (e.g. formal and informal), and effects (e.g. economic, institutional, cultural, academic, innovation and management).

2.1.1 Motivation and Benefits of University-Industry Collaboration

UIC provides a bridge between the business sector and academic institutes whereby they can complement each other's resources. Most researchers agree that UIC is beneficial for both universities and industry, and the motivation and benefits *per se* are discussed in the following paragraphs.

2.1.1.1 Benefits for industry

Universities play a vital role in educating the labour force, generating scientific knowledge, and conducting early-stage development, which initiates technological inventions (Yusuf, 2008). Since technology changes rapidly, external technological collaboration provides firms with an alternative choice to complete their own R&D departments, which can create more technological innovations and shorten the time-to-market of their products (Kurokawa, 1997). From the perspective of inter-firm R&D cooperation, firms engage in joint R&D so that they can gain access to external resources, such as the joint financing of R&D, reducing uncertainty, realising cost-savings, and achieving economies of scale and scope (Becker and Peters, 1998; Robertson and Langlois, 1995; Becker and Dietz, 2004). Thus, more and more firms are tending to become involved in a collaborative arrangement with a university in order to gain access to manpower, research results, and the university's facilities. They are also seeking the solutions to specific problems, and hope to gain a reputation to improve their image (Peters and Fusfeld, 1982). Geisler and Rubenstein (1989) cite 400 cases, and conclude that there are 12 main motivations for firms to cooperate with universities. These include outsourcing R&D activities, access to technology for problem solving, obtaining state-of-the-art information, reducing risks in R&D, cost saving, access to students and professors, and enhancing prestige.

R&D cooperation with a university is an efficient way to gain superior and complementary external resources for Small and Medium-sized Enterprises (SMEs), the business internal resources of which are limited (Okamuro, 2007). Bagchi-Sen (2007) finds that the motivations of US biotechnology firms to pursue a technological collaboration with industries and universities are different. The motivations of inter-firms' technological alliances include gaining access to funds for R&D, the reduction of risk in R&D, quality control in R&D, product development, manufacturing for large-scale trials, the enhancement of credibility and reputation, marketing and distribution, and attracting the attention of third party investors (e.g. venture capital). However, biotechnology firms collaborate with universities for reasons such as obtaining "breakthrough" technologies, finding "early" technologies, gaining access to federal funds, and enhancing their credibility and reputation. The results of studies by Bagchi-Sen (2007) imply that the major difference between UIC and inter-firm technological collaboration is that UIC is knowledge-orientated and science-orientated, while inter-firm collaboration is more profit-orientated.

2.1.1.2 Benefits for universities

In terms of the reasons which motivate universities to interact with industry, they also seek cooperation with an industry to gather more resources and opportunities, including industrial research funding, special technological expertise, practical experience for students or staff, the chance to get employment for graduates, cross-fertilisation across disciplines, obtaining prestige or visibility, pooling knowledge for tackling large and complex problems, and enhancing productivity (Peters and Fusfeld, 1982; van Rijnsoever et al., 2008). The benefits for university researchers to collaborate with firms also include assess to facilities and equipment, new research tools, market information, commercial opportunities, bringing technology into practice, contact with a wider network of scientists, and enhancing scientific knowledge, sharing the industry's intellectual property, and augmenting the university's prestige (Bagchi-Sen, 2007; Scott et al. 2002; Geisler and Rubenstein, 1989; Glenna et al., 2007; Etzkowitz, 2003; Shane, 2004; Welsh et al., 2008). In view of the wide benefits for universities, scholars recommend appointing a policy maker to increase the interactions between university scientists and industrial companies (Kaufmann and Tödtling, 2001; Smits and Den Hertog, 2007; Etzkowitz and Leydesdorff, 2000; van Rijnsoever et al., 2008).

Arvanitis et al. (2008) list 24 motives for universities to collaborate with industry. They conducted a factor analysis and found that a series of motives could be grouped into four main categories, as follows: (1) access to industrial knowledge, such as practical experience, possibilities of application, additional insights, (2) access to additional resources, such as research facilities and business funding, (3) institutional or organisational motives, such as job opportunities, improved image, and commercial success, (4) pursuing higher research efficiency, such as cost and time savings. The empirical results illustrate that these four types of motivation are partially related to informal contacts, attendance of conferences, private enterprises workshops, technical facilities, education and training activities, and research activities. Moreover, the results indicate that only motive 1 is relevant to university research outputs, and it is only relevant to patenting, but not licensing and Spin-offs activities.

2.1.1.3 Research Gap

Although a number of studies describe the motivations of universities and firms to engage in UIC, the literature is inadequate in some respects. Firstly, although these studies provide reasons for UIC, they lack theoretical and systematic frameworks. Secondly, these studies focus on describing, rather than explaining, which means that the framework to enhance the operation and performance of UIC is incomplete. Thirdly, Arvanitis et al. (2008) conducted a comprehensive survey on the benefits for university researchers and university research outputs. However, they measured the benefits according to the perceived importance of each activity, rather than the real benefits acquired from a UIC, and the former is less relevant to university research outputs of UIC activities.

2.1.2 Barriers to University-Industry Collaboration

2.1.2.1 Barriers from University Researchers' Perspective

Despite the appealing benefits, organisations which are involved in UIC continue to confront barriers. Siegel et al. (2004) identify the barriers to university-industry technology transfer as culture clashes, bureaucratic inflexibility, poorly designed reward systems, and the ineffective management of university technology transfer offices. Having surveyed university administrators in prominent US universities, Glenna et al. (2007) found that the disadvantages for universities to engage in UIC could be ranked by their score, from high to low, as increasing potential for conflicts of interest, de-emphasising non-proprietary agendas and basic science research, inhibiting materials transfer, increasing lawsuits over intellectual property, increasing tension between university colleagues, restricting scientific communication among university researchers, undermining the credibility of university scientists, and restricting the ability of faculty members and students to publish.

Arvanitis et al. (2008) explored the obstacles when university scientists collaborate with private enterprises. According to their survey of 241 Swiss university scientists, they characterised a series of obstacles in six categories: (1) lack of confidence in business, and risk of damaging scientific reputation, (2) deficiencies of firms, such as a lack of qualified staff, facilities, uncertainty about R&D results, (3) different interests and attitudes to research, (4) endangering scientific independency, and ignorance of fundamental research, (5) administrative problems, such as property rights, legal restrictions, and lack of support for project administration or commercialisation, (6) lack of human resources for the UIC, such as high teaching loading, and lack of academic specialists. Their empirical results demonstrated that university licensing and spin-off activities were significantly hampered by obstacle 1.

2.1.2.2 Barriers from Practitioners' Perspective

van Dierdonck and Debackere (1988) examined the barriers for an industry which wants to collaborate with a university, and they found several barriers, including: (1)

institutional obstacles for different organisation systems and policy, (2) psychological obstacles for different organisational culture and values, hindrance to cooperation, (3) operational obstacles for raising capital, distributing income, and researchers without business expertise. Siegel et al. (2004) identified eight barriers to effective university–industry technology transfer, including: (1) lack of understanding of university's scientific norms and environment, (2) insufficient rewards for university researchers, (3) bureaucratic and inflexible university administrators, (4) insufficient resources devoted to technology transfer by universities, (5) poor marketing/technical/negotiation skills of TTO, (6) over-expectation of intellectual property rights, (7) faculty members' overestimation of the value of their technologies, (8) the "public domain" mentality of universities. The authors found that entrepreneurs, university scientists, and TTO administrators perceive barriers differently. The authors further examined the perceptions of entrepreneurs, university scientists, and TTO administrators toward the barriers to university–industry technology transfer. According to the results of 55 interviews of mixed samples, most respondents indicated barrier 1, mentioned above, to be the major hurdle of technology transfer. In addition, their results contain some interesting points: entrepreneur respondents identified the barriers to university-industry knowledge transfer to be the insufficient transfer of knowledge to poorly-skilled TTO administrators, and universities' rigid mentality, inflexible policies, and unrealistic intellectual property policy. On the other hand, the TTO respondents asserted that inefficiency is the result of lack of resources, insufficient rewards, and scientists' unrealistic expectations of the value of their technologies. Finally, university scientists perceived insufficient rewards for university researchers and the bureaucracy and inflexibility of university administrators to be the major barriers to university-industry knowledge transfer.

2.1.2.3 Research Gap

Although earlier studies indicate barriers to UIC, these are somewhat deficient. Firstly, there seems to be no general consensus of barriers, because of the different stakeholders' perspectives and diverse samples. Secondly, most studies simply list the possible obstacles to UIC, but put insufficient emphasis on exploring how to overcome them.

2.1.3 University-Industry Collaboration in Taiwan

Taiwan is ranked 8th in the IMD's World Competitiveness Yearbook rankings in 2010 (IMD, 2010a). Taiwan is known for its capacity to innovate, and is ranked 7th for its overall innovation factors among a record number of 139 economies. In detail, Taiwan shows an excellent performance in its utility patents (1st), quality of math and science education (6th), Quality of the educational system (7th), government's procurement of advanced technological products (7th), the availability of scientists and engineers (8th), company spending on R&D (9th), university-industry research collaboration (12th), capacity for innovation (14th), and the state of cluster development (6th) (IMD, 2010b).

Before the early 1980s, there was little collaboration between universities and industry in Taiwan because the Taiwanese *Ministry of Education* (MOE) legislatively prohibited academics from having a formal interaction with industry. In order to improve national innovation and encourage academia and industry to jointly develop key technologies and innovative products, the *National Science Council* (NSC) in Taiwan actively promoted a "University-Industry Cooperative Research Programme" from 1991.

In general, three departments organise the UIC activities in Taiwan. The NSC provides the funding for research projects/activities, and aggregates the outputs, such as reports and papers. The MOE manages the education and training of research personnel, while the *Ministry of Economic Affairs* (MEA) is responsible for industrial development, such as start-ups, science parks, patents, technology, consultancy services, and industrial R&D expenditure (Lee, 2009; Science and Technology Advisory Group of Yuan, 2007a, 2007b). The UIC Promotion System in Taiwan is shown as **Figure 2.1**.

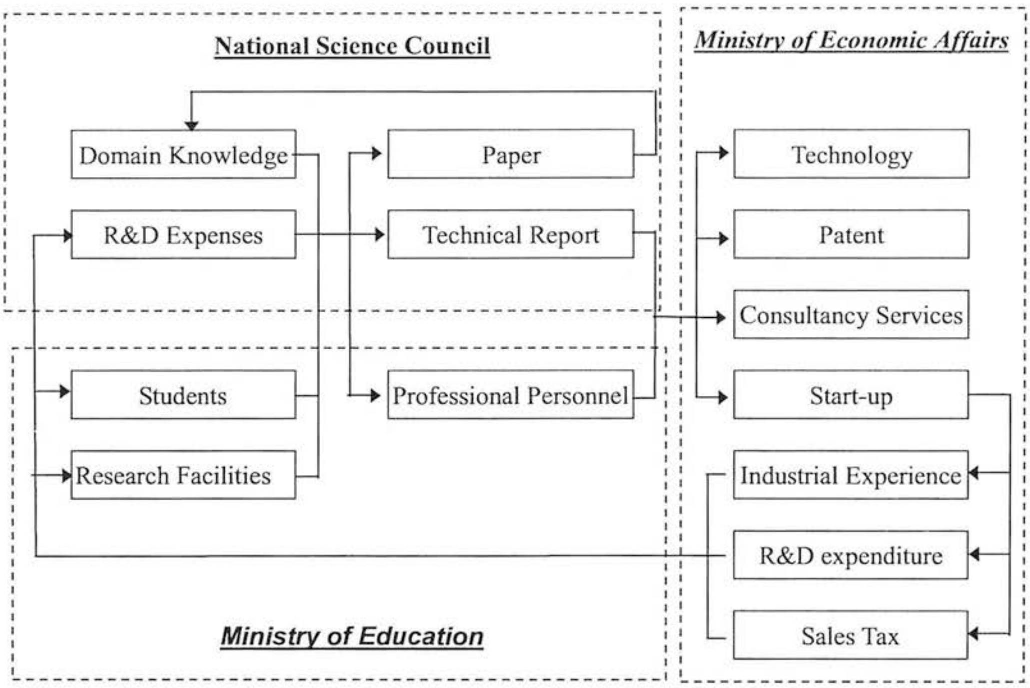

Figure 2.1. University-Industry Collaboration Systems in Taiwan

Source：Science and Technology Advisory Group of Executive Yuan (2007a, 2007b)

Moreover, the *Department of Small and Medium-sized Enterprises* (DSME) of the MOA facilitated the establishment of 82 Innovation and Incubation Centres in university campuses to help to set up incubation firms and transfer knowledge between SMEs and universities. As at 2008, the DSME had assisted the implementation of more than 3,000 incubation firms, and 37 incubations had been listed/over-the-counter. The DSME also provided assistance to these incubation firms to obtain more than 1,500 patents and 700 technology transfers. In order to utilise the resources of various departments, the Taiwanese government further set up a *"UIC Integration and Promotion Programme*" in 2008 to organise the UIC programmes among the NSC, the MOE, the MEA, and other departments.

Table 2.1 University-Industry Collaboration of Higher Education Sectors

	UIC project	UIC Expenditure ($ Million)	Patent Applied	Patent Issued	Technology Transfer
2003	278	5.32	82	34	18
2004	834	15.85	205	61	54
2005	2041	34.77	617	477	177
2006	2093	34.41	458	198	185
2007				248	335
2008				440	412
Total				1444	991

Source: Technological and Vocational Education (2009)

As at November 2009, 8,186 UIC research projects had been conducted by the NSC for experimental development orientation projects (52.9%), applied research orientation projects (44.8%), and basic research orientation projects (2.2%). A total amount of US$199 million UIC research expenditure was allocated for experimental development orientation projects (53.6%), applied research orientation projects (38.0%), and basic research orientation projects (8.3%) respectively. This illustrates that the Taiwanese government encourages academic institutions to cooperate with industry in projects of experimental development and applied research. With the support of the MOE, more than 1458 patents were approved, and more than 1181 technologies were transferred or licensed within the cooperation programmes between industries and Higher Education Sectors (HEIs), including universities and colleges, between 2003 and 2008 (Shown as **Table 2.1**.).

In Taiwan, although a large amount of the R&D expenditure of HEIs is allocated to basic research (47%) and applied research (40%). However, technological development only accounts for 13%. On the other hand, business enterprise sectors spend almost 80% on technological development, and relatively little on basic research (0.4%) and applied research (20%) (Science and Technology Advisory Group of Executive Yuan, 2007a, 2007b). Furthermore, only 2.4% of researchers with a PhD qualification work in the business sector, with 65% of the doctoral researchers going to HEIs (40%) or non-profit sectors (25%). This demonstrates the importance of UIC in Taiwan. The R&D activities gap between academic institutions and the business sector is mainly due to the unbalanced allocation of qualified R&D personnel between business and educational sectors. **Figure 2.2** illustrates the research gap between academia and industry.

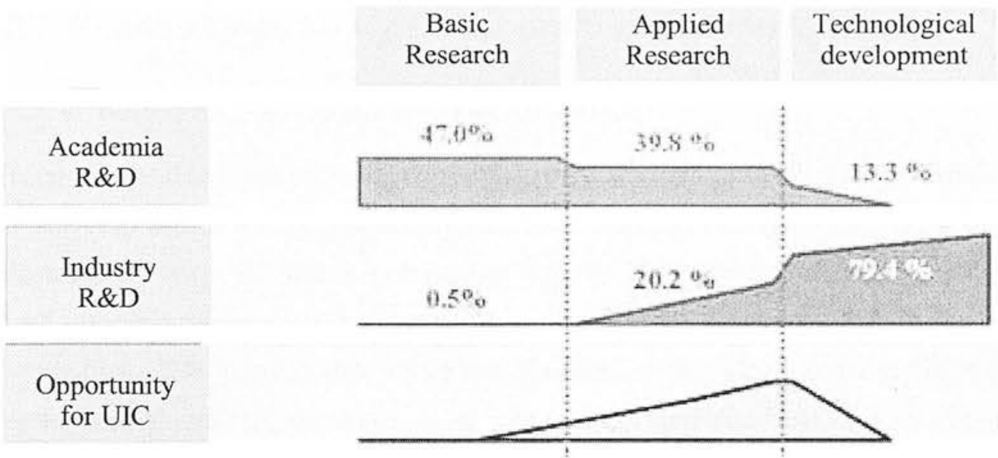

Figure 2.2 Research Gap between Academia and Industry

Source: Science and Technology Advisory Group of Executive Yuan (2007).

In addition, SMEs comprise 98% of the business sector in Taiwan. The UIC characteristics and patterns of SMEs are different from large enterprises in several ways. Firstly, SMEs may especially need to develop more links with universities in order to access R&D funding because of a lack of their own resources (McAdam et al., 2006). Secondly, although SMEs are willing to cooperate with universities, prestigious universities may be reluctant to cooperate with them if they are not qualified, with adequate technological capability (Fontana et al., 2006; Geißler et al., 2009). Thirdly, SMEs may have different motivations than large enterprises for UIC. For example, Santoro and Chakrabarti (2002) found that US SMEs tend to collaborate with universities using the firms' own core technologies, while large enterprises tend to extend their research interests into new fields. Motohashi (2005) also found that Japanese SMEs tend to cooperate with a university in terms of technical consultancy or joint R&D projects which are closer to the final product stage, while large enterprises primarily use joint R&D projects to enhance their internal technological capability in order to obtain long-term benefits. Fourthly, SMEs may be more willing than large enterprises to use the UIC R&D results because of lack of technical capacity (Acs et al., 1994; Motohashi, 2005), and finally, it may easier for universities to transfer knowledge to SMEs due to their flexibility (Colyvas et al. 2002). However, it may be more difficult to transfer knowledge to SMEs due to their resource constraints (Fransman, 2008; Geißler et al., 2009). On this basis, the collaboration and knowledge transfer patterns of SMEs may be different from those of large enterprises.

2.2 University-Industry Collaboration and Performance

2.2.1 Technology Alliance and Performance

Technology alliances and R&D cooperation are alternative methods of internalisation to develop a firm's R&D capability (Kamien et al., 1992). A technology alliance is defined by two or more companies jointly collaborating to develop a new technological innovation by contributing differential resources and technological know-hows (Dodgson, 1993; Tyler and Steesma, 1995; Chen and Lin, 2004). This collaboration enables the partners to share costs and risk, create knowledge and innovation, and further, keep pace with technological advancement in the marketplace. A technology alliance may be established in the form of equity sharing or legal contract agreements to integrate technological activity or exchange technologies (Hagedoorn, 1993; Hagedoorn and Narula, 1996; Chen and Lin, 2004). The impact of technology alliances and R&D collaboration on R&D performance with other firms has been examined by a series of studies with various measurements and samples, and the studies have found that R&D collaboration enhances a firm's performance in areas such as patenting (Shan et al., 1994), product innovation (George et al., 2002; Kelley and Rice, 2002), productivity growth, profitability (Okamuro, 2007), speed and market valuation of initial public offerings (Stuart et al., 1999; DeCarolis and Deeds, 1999) and foreign sales (Leiblein and Reuer, 2004). However, some studies have found that R&D collaboration has a negative effect on a firm's profit or growth (Vonortas, 1997; Janz et al., 2003; Dyer et al., 2007; Okamuro, 2007). The impact of a technology alliance on a firm's growth may be indirect, since such an alliance affects dynamic capabilities, the recognition and exploitation of opportunities, and later, growth. Because the overall business performance is more complex than an R&D-scoped innovative performance (Link and Bauer, 1989; Macpherson et al., 2004).

A technology alliance is regarded to be a useful way to enhance innovation. From the perspective of knowledge transfer, external R&D collaboration facilitate the transfer, sharing, and creation of critical information and knowledge, which in turn, increases innovation performance and provides a competitive advantage for the firm (Inkpen, 2000; Simonin, 2004; Gomes-Casseres et al., 2006; Jiang and Li, 2009). Therefore, external R&D collaboration is not only a source of knowledge, technologies and information, but is also a way for a firm to enhance its ability to absorb external resources and create internal innovation capability.

However, R&D collaboration may lead to disappointing outcomes (Kale et al., 2002; Mora-Valentin et al., 2004; Reuer and Zollo, 2005; Okamuro, 2007; Lhuillery and Pfister, 2009). Not all R&D collaboration is successful, and the failure rate may reach 34% (Reuer and Zollo; 2005), 40% (Kale et al., 2002), or even more than half of the alliances (Kogut, 1989). de Man and Duysters (2005) reviewed 30 empirical articles regarding the relationship between technology alliance and innovation, and found that most studies demonstrate the positive impacts of technology alliances on innovation (73%), while some show neutral impacts (17%) or negative ones (10%). They concluded that alliances are beneficial for innovation when partners are able to share their capability and experience, and have a similar knowledge base. However, if the alliance only has a short lifespan or merely aims to save costs, it may have a negative effect on innovation.

2.2.2 University-Industry Collaboration and Innovation Performance

Unlike inter-firm alliances which engage in R&D, manufacturing and marketing collaboration, UIC is usually involved in R&D and innovation activities. Jiang and Li (2009) indicated that UIC does not always have a direct effect on business profits, but has more of a direct impact on the firm's innovative and commercial performance. Innovation refers to the ability to apply knowledge in order to produce new knowledge and new ideas to create economic value (Bercovitz and Feldman, 2007). Innovation is considered to be a key driver of competitive advantage and firms' growth. The impact of UIC in enhancing the performance of firms and universities has been an important issue in recent debates on the determinants of innovation, and most empirical research shows that UIC is beneficial to innovation productivity for both universities and firms (e.g. Agrawal and Henderson, 2002; Cohen et al., 2002; Feldman et al., 2002; Murmann, 2003, Baba et al., 2009; Abramo et al., 2009). University and research institutions are important sources of obtaining knowledge to complement firms' own internal innovation activities, particularly high technology firms. Arita et al. (2006) examined the relationship between regional cooperation and firms' growth in three major industrial clusters in Japan (Tama, Kinki and Hokkaido). They found that a vertical alliance of suppliers and customers does not contribute to a firm's growth, whereas alliances with "universities" and "cross-industry exchange organisations" show positive effects on firms' growth. Veugelers and Cassiman (2005) find evidence to show that R&D collaboration with universities and research centres complemented the innovation of Belgian manufacturing firms when they cooperated with other firms.

2.2.2.1 Innovation Performance of Universities

In terms of the benefits for universities, university researchers can acquire more valuable resources, such as funding, knowledge, and information to conduct more research. At the individual level, collaborating with industry was found to have a positive influence on the scientific productivity and career success of university researchers and scientists (Lee and Bozeman, 2005; van Rijnsoever et al., 2008). Abramo et al. (2009) examined 1534 co-authored articles in international journals, and the results suggested that university researchers in Italy who cooperated with the private sector demonstrated a superior publication performance than their colleagues who do not cooperate, especially in the fields of medicine and chemistry. In addition, the results also indicated that most collaboration occurred in the fields of medicine and chemistry, while engineering had the highest percentage of co-authored articles of all other fields. On the other hand, Perkmann and Walsh (2008) highlighted consultancy activities within industry, and argued that research-driven consultancy of university researchers may increase their academic productivity more than commercially-driven and opportunity-driven consultancy.

At the university level, Adams et al. (2005) found that the number of scientific outputs of universities grow with more collaboration with industry. Their survey of 89 research-intensive US universities illustrated that the overall patent citation counts of universities are influenced by R&D collaboration with industry. A survey of 122 technology transfer office directors of HEIs in Taiwan also demonstrated that external industrial partnerships, including contract research and collaborative research projects, can facilitate universities' performance in terms of patent grants and licensing incomes, whereas it has no significant impact on the creation of incubation cooperation (Chang et al., 2006). Consistently, a survey of 241 university researchers in Switzerland also show that university researchers' knowledge and technological transfer activities with industry facilitate the commercialisation of university research output in terms of patenting, licensing and spin-offs (Arvanitis et al., 2008).

In Summary, empirical results show that industrial R&D collaboration enhance the R&D productivity of university researchers at an individual level, and improve university innovation performance in terms of numbers of publications, patents or patent citations (Arvanitis et al., 2008; Chang et al., 2006; Owen-Smith and Powell, 2003), licensing activities (Chang et al., 2006; Arvanitis et al., 2008; Horng and Hsueh, 2005) and spin-off activities (Arvanitis et al., 2008; Chang et al., 2006).

2.2.2.2 Innovation Performance of Industry

Other groups of studies emphasise the outcome for the private sector when firms engage in UIC. Firms' innovation output of collaboration varies with different types of partners. For example, Liebeskind et al. (1996) found that biotechnology companies engaged in joint research with academic institutions are more successful at sourcing new scientific knowledge. Miotti and Sachwald (2003) found that a firm's collaboration with customers and suppliers increases its share of innovative products, whereas collaboration with a public academic institution improves its patenting performance. On the other hand, Belderbos et al. (2004) proposed that collaboration between suppliers and competitors positively affects labour productivity growth, while collaboration with universities and research institutes increases firms' innovative sales.

The positive impact of UIC has been found throughout countries with a wide variety of firms' R&D productivity, such as the R&D investment rates of biotechnology science firms (Nelson, 1986), new technology and process development (Mansfield, 1995), patenting rates of US firms (Adams et al., 2001), the patents of Austrian high-technology industries (Fischer and Varga, 2003), patents of large Swedish firms (Lööf and Broström, 2008), a number of patent applications from the Japanese advanced materials industry (Baba et al., 2009), new product development of German firms (Aschhoff and Schmidt, 2008), the sales of new products per employee of Swedish manufacturing firms (Lööf and Broström, 2008), and the growth of sales attributable to market novelties of Dutch firms (Belderbos et al., 2004).

Codified outputs, such as patent and new product development, seem to be the most widely used indicators of industrial innovation. George et al. (2002) conducted a survey of 2,500 university alliances formed by 147 publicly traded biotechnology companies, and they found that UIC facilitated the biotechnology firms to obtain more patents, but it did not increase the number of new products under development, or improve the overall financial performance. This reflects a unique aspect in that, when industry is engaged in long, complex and high-risk projects and product development cycles, it may take a long-term perspective.

Moreover, the discrepancy between the interests of industrial and academic partners may lead to a disappointing innovation improvement. For example, public researchers may pay less attention to the market value and the urgent deadline of the business. They usually prefer to publish their research findings as soon as possible, while companies tend to want to keep the results secret until they have been patented. The gap in the technological distance between universities' basic research orientation and private company's applied research orientation may result in the failure of the innovation project (Dasgupta and David, 1994; Lhuillery and Pfister, 2009). Given these difficulties, UIC may not always guarantee a successful innovation project and better innovation performance.

From the perspective of knowledge transfer, R&D collaborative activity is an important form of knowledge transfer (Meyer-Krahmer and Schmoch, 1998). However, while a number of studies examine the determinants of university-industry knowledge transfer activities (e.g. Rosell and Agrawal, 2009; Giuliani and Arza, 2009; Acworth, 2008; Østergaard, 2008; Yusuf, 2008; Bekkers and Bodas Freitas 2008; Siegel et al., 2003b, 2004; Horng and Hsueh, 2005), there is relatively sparse literature to indicate the impacts of UIC knowledge transfer activities on firms' innovation performance from the perspective of knowledge transfer. Sherwood and Covin (2008) found that the level of technological experts' communication with universities is predictive of the success of acquiring technological knowledge in terms of both tacit and explicit knowledge. Baba et al. (2009) identified three types of university scientists: Star scientists (excellent publication for conducting pure basic research), Pasteur scientists (high publication and patent applications), and Edison scientists (conducting pure applied research). Having surveyed 455 advanced material firms in Japan, they find that the most effective form of collaboration to increase firms' patents was to cooperate with "Pasteur scientists". The empirical studies of UIC and innovation performance are summarised in **Table 2.2**. According to which previous UIC studies focused on confidential and explicit knowledge transfer, such as publications, patenting, and licensing. There are fewer studies to examine tacit knowledge transfer activities, since tacit knowledge is hard to measure, and hard to share and transfer to another person by writing it down.

Table 2.2 Studies of University–Industry Collaboration and Performance

Author (s)	Topic	Sample/ Methodology	Variables (Independent ➔Dependent)	Key findings
Abramo et al. (2009)	Performance of UICs by university researchers	1534 Co-authoring articles, Italy, bibliometric analysis with Data base	NA	This shows that the university researchers who cooperate with private sectors have better co-authoring performance. However, the impact factor of journal research co-authored by industry is that it is lower than that co-authored with other entities. In addition, most collaboration occur in the fields of medicine and chemistry, while it is industrial and information engineering which shows the highest percentage of co-authored articles in the whole field.
Baba et al. (2009)	Universities' "Pasteur scientists" and firms' innovative performance	455 photocatalysis firms in Japan, binomial regression model with database	Collaboration with Pasteur scientists, Star scientists, and Edison scientists ➔ Firms' R&D productivity (number of patents application)	This defines three types of scientists: Pasteur scientists (excellent patent applications and publication), Star scientists (excellent publication for conduct pure basic research), and Edison scientists (pure applied research). It shows that collaboration with Pasteur scientists increases firms' R&D productivity. In contrast, collaboration with Star scientists exerts little impact on firm's output.
Chang et al. (2006)	Determinants of academic innovation	122 directors of TTO in Taiwan, Questionnaire, regression	Intellectual property managerial capability, industrial partnership, and university's entrepreneurial orientation ➔ patent creation, licensing creation, firm incubation	Intellectual property managerial capability, external industry partnerships, and academic entrepreneurial orientation are useful to distinguish the university's innovation performance on academic innovation of HEIs. Also, government support and commitment on research plays a moderating role in academic innovation.
Fischer & Varga (2003)	Knowledge spillovers and regional knowledge production	University in Austria, Economic Analysis, Database	University research and corporate R&D investment ➔ Production function of knowledge and patents	Confirms the mediating effects of geography when knowledge spills over from universities to regional high-technology industries.

Table 2.2 Studies of University–Industry Collaboration and Performance *(Cont.)*

Author (s)	Topic	Sample/ Methodology	Variables (Independent →Dependent)	Key findings
Horng & Hsueh (2005)	Transfer of Scientific Knowledge from universities to firms	4 universities in Taiwan, case study and interview	NA	Universities provide greater rewards for faculty involvement in technology transfer or university allocate more resources to the UIC improve generating more licenses. Moreover, TTO members with marketing experience and skills will expend greater effort in promoting technology to firms.
Jiang & Li (2009)	Knowledge management and innovative performance	127 German managers, structural equation modelling	Alliance scope, alliance governance (JVs vs. contractual alliances) → knowledge sharing, knowledge creation → Partner firms' innovative performance.	This investigates ways in which alliance characteristics affect inter-firm knowledge sharing and creation. It shows that (1) JVs are more effective and influential in facilitating knowledge sharing and creation. (2) alliance scope, positively associated with knowledge sharing, has no effects on knowledge creation. (3) knowledge sharing and creation and their interaction contributes to partner firms' innovative performance.
Kodama (2008)	Role of intermediations and absorptive capacity in UICs	214 firms in TAMA (120 member & 94 others, questionnaire survey	R&D expenditure → Patent applications, new products, new processing technologies put into practical use	This analyses the role of intermediary organisations and absorptive capacity in building a regional universities-firm technology transfer system. It finds that firms which have developed an absorptive capacity in particular touching upon the tacit knowledge aspect.
Perkmann & Walsh (2008)	Academic consultation and its impact on universities and industry	NA, Only Hypotheses developed	Academic consultancy → Research productivity	This identifies academic consultation: opportunity - driven, commercially - driven, and research -driven consultancy. It postulates that consultancy has a limited impact on biasing academic research towards more 'applied' themes. Furthermore, research-driven consultancy may be positively associated with research productivity, but opportunity-driven consultancy will have a negative impact.
Sherwood & Covin (2008)	Successful UIC knowledge acquisition	104 industry managers, questionnaire survey	Partner Trust, Experience Factors, Partner Interface Mechanisms→ UIC knowledge acquisition success	This applies the learning theory to examine determinants of UIC knowledge acquisition success. It is shown that partner trust predicts the successful acquisition of tacit knowledge but not explicit knowledge. Both forms of knowledge are predicted by partner familiarity and communications between the partners' technology experts.
Siegel et al. (2003)	Commercial knowledge transfers from universities to firms	177 UK firms, regressions	Location on university science parks →Research productivity	This examines 88 firms in science park firms and 89 firms in non-science park to investigate whether or not companies located on university science parks have higher research productivity. The results show that university science parks are alleged to stimulate technological spillovers.

Table 2.2 Studies of University–Industry Collaboration and Performance *(Cont.)*

Author (s)	Topic	Sample/ Metho -dology	Variables (Independent →Dependent)	Key findings
van Rijnsoever et al. (2008)	RBT on the interaction of university researchers	304 university researchers in The Netherlands, Questionnaires	Global innovativeness, work experience, dynamic of the scientific field →Academic rank, network activity	This shows that networking with faculties and researchers from other universities stimulates careers, while interaction with industry does not. The personality trait "global innovativeness" facilitates science - science interaction, but not science - industry interaction.
Bercovitz & Feldman (2007)	Firms' innovation strategy and UICs	45 R&D executives, in-depth interviews	Internal R&D strategies →UICs	This shows that universities are preferred when firms perceive potential conflict over intellectual property.
Veugelers & Cassiman (2005)	Firm/ industry characteristics and UICs	Community Innovation Survey data for Belgian manufacturing industry, Regression	Firm's size, cost, risk, own R&D capacity (absorptive capacity), internal know-how capabilities, firms with foreign headquarters →Industry Science Links	This confirms that large/ chemical/ pharmaceutical firms are more likely to be involved in industry science links. UICs are typically formed to share costs but not risk. They find no evidence of the importance of the capacity to appropriate returns from innovation to explain cooperative agreements with universities.
Owen-Smith & Powell (2003)	The role of university patenting in life sciences	Panel data from 89 US universities, interviews with two academic licensing offices	Technology transfer experience, Scientific capacity, Scientific impact, Network →Patent citation counts	This shows that technology transfer experience (patents) and scientific capacity (life science and medical articles) are positively related to patent performance. Scientific impact (Life science impact and Medical impact) has no effect on patents, and too many linkages can preclude patents.
Arita et al. (2006)	Effects of regional cooperation on firms' growth	3 major industrial clusters in Japan, regression	Firms' size and age, cooperation→ Firm growth rate	This shows that (1) vertical cooperation (with suppliers, and customers) does not contribute to firms' growth; (2) the clusters do not enjoy "urbanisation economies";(3) alliances with universities and cross-industry have a positive effect on firms' growth
Adams et al. (2005)	Effects of scientific teams' size and institutional collaboration	Papers written in 110 U.S. universities, Regression	Size of scientific teams (number of authors of scientific papers) → Institutional collaborations	This shows that scientific output and influence increase with team size, and that influence is enhanced by institutional collaboration.
Baldini et al. (2006)	Institutional changes and universities' patenting activities	Italian universities' patenting between 1965-2002, negative binomial regression	University's size, presence of a medical school, geographical location, university's previous patenting performance, IPR regulation → University's patent applications	This shows that (1) the number of Italian universities' patents rose substantially from 1965 to 2002; (2) after controlling universities' characteristics, previous patenting activity and time trends, patenting activities almost triple with an internal IPR regulation; (3) each time a university creates its own patent regulation, there is a 9% increase in the likelihood that universities without an internal patent regulation will adopt one.

Table 2.2 Studies of University–Industry Collaboration and Performance *(Conti)*

Author (s)	Topic	Sample/ Methodology	Variables (Independent →Dependent)	Key findings
Rothaermel & Thursby (2005)	University –firm knowledge flows and firms' performance	79 incubator firms (Database), Regression analysis	Knowledge flow factors (university license, absorptive capacity) →Incubator firms' performance	The evidence suggests that incubator firms' absorptive capacity is an important factor of their performance.
Rosell & Agrawal (2009)	Knowledge flows between university and industry	Biotech & pharmaceutical in outflow case; electronics in inflow case, Patent Data	NA	This shows that (1) university diffusion premium (university knowledge outflows are more widely distributed than those of firms) declined by more than half during the 1980s; (2) University diversity premium (degree to which knowledge inflows used by universities are drawn from a more widely-distributed set of prior art holders than those used by firms) also declined by more than half.
Arvanitis et al. (2008)	University scientists' perception of UICs	241 Swiss university researchers, Questionnaire survey.	Motivation and obstacles → university patenting, licensing & spin-offs.	This identifies the motivation and obstacles, and knowledge transfer activities of UICs (e.g. Informal informational contacts, using technical facilities, educational activities, research activities, consultancy). It shows that (1) UICs tend to have stronger applied research orientation and lower teaching obligations; (2) An institute's research focus does not influence its propensity for patenting and spin-offs; a focus on basics research seems to be quite compatible with licensing activities.
Okamuro (2007)	The effect of organi-sational and contractual characteristics on R&D collabo-ration	Japanese manufacturing SMEs, Database in 2002, Probit Regression	Organisational characteristics (membership structure, partner relationship, external support), Contractual characteristics (rules of cost and outcome sharing)→ cooperative R&D Success	The results suggest that "the higher the quality and quantity of external resources available through cooperation", and "the lower the transaction and coordination costs", the more successful the cooperative R&D.
Østergaard (2008)	Knowledge flows through social networks	346 engineers and computer scientists from 19 firms in Denmark, Questionnaire survey, logistical regressions	1. Mobility →Informal contacts 2. Mobility, Employees' experience, education, and absorptive capacity →Acquiring knowledge through informal contacts	This examines informal contacts between employees in firms and local university researchers. It shows that (1) there are more inter-firm informal contacts than university informal contacts; (2) knowledge is more frequently acquired from engineers in other firms than through UICs; (3) Engineers who have participated in formal projects with university researchers, and engineers who are educated at the local university, are more able to acquire knowledge from informal contacts with university researchers.

2.2.3 Innovation Outputs of University-Industry Collaboration

There are a variety of methods to investigate the innovation productivity of firms in alliances and UICs. In accordance with the literature review, the most popular indicators of innovation productivity in a UIC are discussed below. These include publications, patents, knowledge acquisition, new product developments, spin-offs, and licenses.

2.2.3.1 Publications and Patents

Cohen et al. (2002) found that published papers and reports are the most important and widespread ways to access university knowledge across industries, and patents and meetings are also regarded as being important. The results of a Dutch survey demonstrated that both industrial researchers and university researchers agreed that scientific publications and patent texts are the most important channels by which to propagate university knowledge among 23 UIC knowledge transfer channels (Bekkers and Bodas Freitas, 2008).

The codified outputs of academic research, such as publications and patents, are widely-adopted indicators of the output of academic research and industrial innovation (e.g. Narin et al., 1997; McMillan et al., 2000; Tsai, 2001; Caloghirou et al., 2004), because they have the advantage of simple, objective, clear, and available archived data. For example, Abramo et al. (2009) used a bibliometric analysis to examine university researchers' performance in a number of jointly co-authored articles in international journals between researchers in universities and the private sector. The bibliometric analysis approach was developed to provide a systematic basis to measure the quality of technical papers according to the number of papers published in prestigious journals and the number of the papers which have been quoted. Their results showed that university researchers who cooperate with the private sector have more publications than those who do not cooperate. However, a lower number of factors impact co-authoring publications with industry than with other entities. Patents are the other most widely-used indicators of innovation output. Although patents can only provide a limited reflection of the real quality and value of innovation (Lanjouw and Schankerman, 2004), they are still the most popular innovation index, and researchers attempt to use patent citations to evaluate the quality of a patent (Beneito, 2006; Jaffe et al., 1993). For example, Baldini et al. (2006) applied patenting activities to assess Italian universities' research performance, and the results showed that the number of Italian universities' patents increased substantially between 1965 and 2002. Owen-Smith & Powell (2003) employed the number of life science patents to assess medical universities' research performance, and their findings suggested that an increased volume of patenting led to higher impact patent portfolios at US universities. Jiang and Li (2009) used patent counts, patent citations and new product counts to assess the innovation performance of alliances, and found that innovation performance is affected by inter-firm knowledge-sharing and creation. Baba et al. (2009) used the number of patent applications as an indicator of firms' R&D productivity of UIC, and they found that collaborating with Pasteur scientists is the most effective way to enhance advanced material firms' R&D productivity, rather than collaborating with Star scientists and Edison scientists.

An industrial citation of university publications or patents is a way of examining the performance of knowledge transfer from universities to firms (Jaffe et al., 1993; Trajtenberg et al., 1997; Henderson et al., 1998; Rothaermel and Thursby, 2005). Narin et al. (1997) examined papers cited in US industry patents and found that 73% of those papers were generated by academic researchers, and the remainder by industrial scientists. Agrawal and Henderson (2002) find a rising trend of industrial patents citing academic research. Murray and Stern (2007) and Branstetter (2010) also found support for this phenomenon. Fischer & Varga (2003) examined corporate patents as a proxy for knowledge spillover from university research activities to regional knowledge production in high-technology industries in Austria, and they found that geographically mediated knowledge spillover performance was important. Rosell and Agrawal (2009) distinguished the two types of knowledge flow with a number of patents and patent citations in UICs: knowledge outflow (for knowledge produced by universities), and knowledge inflow (for knowledge consumed by universities). Their empirical survey indicated that knowledge outflow of drugs and biotechnology , and knowledge inflow to the electronics industry, declined by more than half during the 1980s.

2.2.3.2 Spin-offs and Licensing

Spin-offs and licenses are used as indicators of universities' output of UIC. For example, Chang et al. (2006) used licensing income, the number of newly-entered incubating firms and patent grants, to measure the innovation performance of HEIs in Taiwan, and they found that a university's capability and partnership with industry are useful to distinguish the university's innovation performance. Arvanitis et al. (2008) similarly used the number of licenses, spin-offs, and patents to indicate the commercialisation outputs of universities for university-industry knowledge and technology transfer. Based on a sample of Swiss public science institutes during the period 2002–2004, they found that 34.4% of the institutes said that patent applications helped the operation of spin-offs, while 12.2% of them cited licenses, and 22.2%, institutes. On the other hand, several studies infer that spin-offs and licenses are forms by which universities collaborate with industry (e.g., Wright et al, 2008; Bekkers and Bodas Freitas 2008; Boardman, 2008; Yusuf, 2008; Perkmann and Walsh, 2008; Eun et al, 2006; O'Shea et al, 2007). This study argues that spin-offs and licenses play multiple roles in universities in UIC, since on the one hand, they are collaboration agreements which facilitate knowledge transfer and the exchange of resources. On the other hand, they are also indictors of the outputs for universities and technology transfer offices in UIC activities. In terms of industry, firms are more interested in accessing universities' technology, knowledge and resources through spin-offs and licenses, and pay less attention to increasing the number of these. Therefore, spin-offs and licenses are collaborative forms for the business sector rather than innovation outputs. The role played by spin-offs and licenses in knowledge and technology transfer will be discussed in chapter 2.7. and chapter 3.

2.2.3.3 New Product Development

Although new product development is criticised as to whether or not it uses appropriate methods to assess innovation (Beneito, 2006), the number and sales of new products are still the most frequently used indicators of new product innovation and commercial success (e.g. Jiang and Yuan, 2009; Becker and Dietz, 2004). As yet, there is no conclusive evidence of the relationship between UICs and new product development. Some researchers find that UIC enhances new product development (Aschhoff and Schmidt, 2008) and the sales of new products per employee (Lööf and Broström, 2008). Conversely, Miotti and Sachwald (2003) found that cooperation between universities and public institutions has no significant impact on the firm's share of innovative products in terms of sales. Hall et al (2003) and Bougrain and Haudeville (2002) even found that UIC has a negative effects on commercial success, because universities tend to be involved in more difficult projects, which are unlikely to completed soon, and which have a lower probability of early completion. Kodama (2008) used the number of patent applications, new products, and new processing technologies to characterise a firm's R&D outcomes of inter-firm linkage and university-industry linkage, and found that university linkage is effective for patent applications which often depend upon basic research, whereas inter-firm linkage appears to be more effective for new product creation which requires business resources related to the market. Similarly, Okamuro (2007) used patents and sales growth to assess a firm's technological and commercial success of R&D cooperation. His survey of Japanese SMEs shows that cooperation with large firms and familiar firms in other industries contributes to technological success, while cooperation with many firms is favourable for commercial success. However, he found that UICs contribute to technological success, but have a negative effect on commercial success, because UIC projects are usually at an early stage, still far from commercialisation, and firms are more likely to cooperate with universities on basic research projects that are not meant for commercialisation.

2.2.3.4 Knowledge Performance

Acquiring Knowledge from external partners is a key factor for a firm to sustain success and competition (Hamel, 1991), and this is particularly critical to a firm's innovation performance (Nonaka and Takeuchi, 1995). From the perspective of knowledge, collaboration provides various kinds of diverse sources of knowledge, and opportunities for mutual learning and internal learning, and a firm's technological knowledge and ability in R&D activities can be accumulated to develop new products, processes or services, and thus, enhance its innovation outcomes (Sherwood and Covin, 2008; Jiang and Li, 2009). From a sample of 346 engineers in Denmark, Østergaard (2008) found that one third of the respondents had informal contacts with university researchers. 45% of the respondents who had links with universities indicated that the knowledge they had acquired from university researchers could be applied to resolve their technical problems. Jiang and Li (2009) find that creating and sharing knowledge significantly contributes to the performance of inter-firm knowledge transfer, and it further affects partner firms' innovative performance. In addition, explicitly codified knowledge is a part of the output of knowledge transfer activities. A survey of 104 industry managers by Sherwood and Covin (2008) found that partner familiarity, partner trust, and communication between partners' technological experts influenced the acquisition of tacit knowledge from universities, but these determinants demonstrated no significant effect on explicit knowledge acquisition.

2.2.3.5 Research Gap

Table 2.3. illustrates the indicators of UIC innovation performance for universities and industry. The table of the relevant literature shows the research gap of UIC

performance. Firstly, there is a lack of the consistent operationalisation of UIC performance. Secondly, the codified indicators are still criticised because they are not able to assess the commercial value of patents and are unable to count new inventions and technologies which are not patentable (Laursen and Salter, 2004; Jiang and Li, 2009). Publications, patents, and new product developments are the most widely-used indicators of industrial innovation performance. However, these codified outputs only look at part of innovation productivity and the commercial success of innovation. And thirdly, it takes time to conduct UIC projects and absorb the knowledge acquired from universities, and the impact of UIC may not be immediately reflected in the codified output. Fourthly, the increase in codified outputs may partly be attributed to the firm's own internal innovation activities, making it hard to evaluate the contribution from UIC.

Table 2.3 Indicators of University-Industry Collaboration Performance

	Publication	Patent	Patent Citation	Patent Application	License	Spin-offs	New Product Development	Knowledge Acquisition	Others
Abramo et al (2009)	U/F								
Agrawal & Henderson (2002)	U		F						
Arvanitis et al. (2008)		U			U	U			
Aschhoff & Schmidt (2008)							F		
Baba et al. (2009)				F					
Baldini et al. (2006)		U							
Branstetter (2010)	U		F						
Bougrain & Haudeville (2002)							F		
Chang et al. (2006)		U			U	U			
Fischer & Varga (2003)		F							
Hall et al. (2003)							F		
Jiang & Li (2009)		F	F						F [a]
Kodama (2008)				F			F		
Lööf and Broström (2008)							F		
Miotti & Sachwald (2003)							F		
Murray & Stern (2007)	U		F						
Narin et al. (1997)	U/F		U/F						
Okamuro (2007)		F							F [b]
Owen-Smith & Powell (2003)		U							
Østergaard (2008)								F	
Rosell & Agrawal (2009)		U/F	U/F						
Sherwood & Covin (2008)								F	

Note: U=University performance, F=Firm performance, [a] = Technology development, [b]=Sales growth

2.3 Resources and University-Industry Collaboration

2.3.1 Resource-based Theory and Alliances

2.3.1.1 Resource-based Theory

The Resource-based theory (RBT) emphasises the strategic resources of a firm and views a firm as a unique bundle of assets and resources (Wernerfelt, 1984). Researchers have attempted to explore the fundamental factors which create a sustainable competitive advantage within organisations, and have posited that, if a firm's resources have the characteristics of value, rarity, limitability and non-substitutability, then these are likely to constitute a source of competitive advantage (Barney, 1991). If firms devote more effort to their resources and employ them in distinctive ways to create valuable and inimitable resources, they are more likely to survive in a competitive and fast-changing environment.

Grant (1991) maintains that a firm's resources consist of tangible resources (e.g. financial capital, physical equipment), intangible resources (e.g. intellectual property, reputation, firm culture, and organisational structure), and human resources. Intangible resources and human resources appear to be more likely to contribute to the creation of competitive advantages and internal capabilities, and they are particularly significant predictors of value creation and performance (Leitch and Harrison, 2005). Li and Chen (2009) used RBT to explain the effects of business resources on technology venture performance, and they found that firms with greater internal endogenous resources, such as technology, marketing, teams, and financial resources present a higher business performance compared to their business plan and compared to other similar businesses. However, exogenous resources, such as opportunity and embeddedness do not appear to have a significant effect on business performance.

2.3.1.2 Resource-Based Theory and Alliance

The primary motivations for strategic alliances are access to resources and the ability to shorten the time required for development. Alliances arise when firms need resources from outside, or when firms tend to exploit their resources to create alliance opportunities (Yasuda, 2005; Kasch and Dowling, 2008). The RBT was extended to explain inter-firm alliances, since all organisations must engage in exchange with others to obtain resources (Chen and Lin, 2004; Lavie, 2006). Lavie (2006) argued that firms engaging in an alliance create a resource-based competitive advantage in terms of economic rent. The rent is caused by controlling scarce resources, exchanging and co-developing idiosyncratic resources, gaining the partner's resources, and utilising the firm's scarce resources. Because firms differ in terms of their resource portfolios and their ability to bundle resources within a portfolio, collaboration enables them to create synergistic benefits.

There have been previous research attempts to employ the RBT and the TCE to explain alliance activities (e.g. Lin, 2006; Chen and Chen, 2003; McIvor, 2009; Gulbrandsen et al., 2009), and the researchers have found that the RBT contributes a great deal to explain alliance decisions, whereas the TCE contributes relatively less (e.g. Kasch & Dowling, 2008; Yasuda, 2005). The RBT is further applied to explore outsourcing activities. For example, McIvor (2009) and Gulbrandsen et al. (2009) argue that, when a firm gains no advantage from performing certain activities internally, or it lacks the necessary resources to perform them internally, it will seek to outsource those activities with external providers. Calantone and Stanko (2007) examined the drivers of outsourced innovation and found that firms' resources enable innovation managers to better target perspective clients from firms seeking contract innovation business.

The knowledge resource has been viewed as being the critical element to create organisational capabilities to gain a competitive advantage (Barney, 1991), and an increasing number of studies explore the role of knowledge in collaboration. For example, Lee (2007) used a sample of 189 Taiwanese biotechnology firms, and found that alliances improve SMEs' performance of new product development and commercial success, particularly with partners with a high level of technical capacity and a good relationship. West and Noel (2009) explored the impact of knowledge resources on business performance, and they found that a firm's experience of start-up is important to the performance of new venture companies. Craighead et al. (2009) found that a firm's knowledge of supply chains enhances product-specific responsiveness and action, and further creates the superior financial performance of the firm. Jiang and Li (2009) examined the effects of knowledge management on innovative performance and found that knowledge sharing and creation between members contributes to partner firms' innovative performance. In addition, from a knowledge-based perspective, a firm's competitive advantage arises from its knowledge, and it is argued that the knowledge can be originated internally, or be acquired externally through purchasing or cooperation (Meeus and Oerlemans, 2004; van Rijnsoever et al., 2008), and collaboration enables firms to access valuable knowledge resources to gain a competitive advantage. Literature which employs the RBT in collaboration is summarised in **Table 2.4**.

Table 2.4 Studies of Resource-Based Perspective and Collaboration

Author(s)	Topic	Sample/ Methodology	Variable(s) (Independent →Dependent)	Key findings
Calantone & Stanko (2007)	Drivers of outsourced innovation	Industry database, regression analysis	Exploratory research performed, inventory turnover, profit margin, represent importance of core competencies, and learning effects →Outsourced innovation	This shows that the exploratory research performed and the profit margin is significant to outsourced innovation. The drivers allow for better resource planning from innovation managers in traditional firms, as well as the better targeting of perspective clients from firms seeking contract innovation business.
Chen & Chen (2003)	Governance structures in strategic alliances	159 Taiwanese firms, Questionnaires , Probit regression	Assets specificity, uncertainty (technological, behaviour), resource complementarity → Governance structures	This examines the pattern of resource alignment in strategic alliances, and its relevance to the scheme of cooperation. The TCE is shown to be powerful in explaining the choice between joint ventures and contractual alliances, while the RBT provides useful insights into the choice between two forms of contractual alliances (exchange and integration alliances). It also shows that small firms are more inclined to enter contractual alliances as opposed to joint ventures.
Chen (2004)	Knowledge attribute, alliance, and knowledge performance	137 alliance cases, Questionnaire, regression analysis	Explicitness of knowledge, firm's absorptive capacity, trust, and adjustment →Knowledge transfer performance	This shows that (1) equity-based alliances are more effective than contract-based alliances in transferring knowledge (2); equity-based alliances are more effective in transferring tacit knowledge, while contract-based alliances are more effective in transferring explicit knowledge (2); trust and adjustment have a positive effect where there is conflict.
Craighead et al. (2009)	The effects of knowledge of supply chains on performance	Archival data of 489 firms	Knowledge of supply chains (knowledge development capacity, intellectual capital) →Firm performance.	This shows that firm-level performance is influenced by the knowledge of supply chains, such as knowledge development capacity and intellectual capital complement alternative chain strategies.
Gulbrandsen et al. (2009)	Antecedents of vertical integration	114 mangers, hydroelectricity industry, questionnaires survey, Regression	Asset specificity, relatedness (closeness to present competence, tacit knowledge)→ Vertical integration	The TCE and RBT are applied to investigate the antecedents of vertical integration. Asset specificity and "closeness are shown to present competence" and are positively related to vertical integration, while "tacit knowledge" is negatively related to vertical integration/in sourcing.
Kasch & Dowling (2008)	Intermediate forms of cooperation	Young US biotechnology firms, Content analysis of annual	Commercial activities (appropriability of regime, competition), resources (direct /indirect capabilities, synergies between products), financial resources, asset specificity, uncertainty →Commercial strategy	This shows that the propensity to integrate is related to the appropriability of the regime, direct capabilities, synergies between the products, and financial resources. It also shows that the RBT contributes a great deal to explain commercialisation strategies, whereas the TCE contributes less.

Table 2.4 Studies of Resource-Based Perspective and Collaboration *(Continued)*

Author(s)	Topic	Sample/ Methodology	Variable(s) (Independent →Dependent)	Key findings
Lee (2007)	Alliances and SMEs performance	189 Taiwanese biotech firms, questionnaire survey, structural equation modelling	Alliance structure and type, absorptive capacity, partners' technical capacities and relationship → New ventures success	The results shows that alliance structure, alliance type, absorptive capacity, partners' technical capacities, and partners' relationship, all positively facilitate new ventures success in terms of new product development performance and commercial success. In addition, alliance structure improves absorptive capacity.
Leitch & Harrison (2005)	TTOs and spin-off commercial isation activities	Longitudinal case study: Queen's University in Belfast	NA	This discusses the efficacy and appropriateness of TTOs becoming involved in spin-off commercialisation activities. Different types of resource flows are discussed: finance, advice, support, people, technology, ownership.
Li & Chen (2009)	The firm's endogenous /exogenous resources and performance	56 Respondents in Taiwan's incubation centres, Structural equation model analysis	Endogenous resources, exogenous resources (opportunity, embeddedness) → Firm's performance	This shows that endogenous resources (technology, marketing, team, finance) are positively related to firm performance. Opportunities and embeddedness do not significantly affect a firm's success directly, but they shape endogenous resources.
Lin (2006)	Collaborati on and its success in value creation	NA	NA (only hypotheses development)	This employs the TCE and RBT to explain inter-firm alliances and value creation. It discusses strategic resources (information asymmetry, causal ambiguity, immobility, inimitability), transaction modes (contractual agreement or equity holding vs. M&A), embeddedness (relational, structural, positional), and outcomes of value creation.
McIvor (2009)	How firms inform outsourcing evaluation.	3 case study	NA (only hypotheses development)	This employs the TCE and RBT to explore the firm's outsourcing evaluation. It postulates that an organisation's superior resource position or high potential for opportunism leads to internalisation, and an organisation's weak resource position or low potential for opportunism leads to outsourcing.
West & Noel (2009)	The impact of knowledge resources on new venture performance	83 CEO, technology-ba sed firms, Regression analysis.	Industry/business relatedness, previous start-up experience, networking (information newness, frequency) → Firm performance	This shows that relatedness (industry relatedness, business Relatedness) and three types of procedural knowledge (previous start-up experience, networking frequency, and networking information newness) are important at start-up.
Yasuda (2005)	Formation of strategic alliances in high-tech industries	40 cases in the semiconductor industry, Case study.	NA	This identifies four forms of technology-driven strategic alliances: technology license, joint R&D, sourcing agreement, and joint venture. The results conclude that the RBT prevails over the TCE when explaining alliance activities in high-technology industries.

2.3.2 Empirical Studies of Resources and University-Industry Collaboration

The determinants and drivers of UICs have been a key issue in recent debates. Researchers have attempted to explore the factors which may affect UIC activities at firm-level, industry-level, and individual-level, such as universities' collaboration with firms (e.g. Horng and Hsueh, 2005; Veugelers and Cassiman, 2005), university researchers working with firms (e.g. Boardman and Ponomariov, 2009), the creation of university spin-offs (e.g. Eun et al., 2006; Powers and McDougall, 2005; O'Shea et al. 2005; Landry et al., 2006; Lockett and Wright, 2005; Leitch and Harrison, 2005), industrial collaboration with universities (e.g. Segarra-Blasco and Arauzo-Carod, 2008; Østergaard, 2008; Tether and Tajar, 2008; Stuart et al., 2007; Bagchi-Sen, 2007; Bercovitz and Feldman, 2007; Laursen and Salter, 2004; Bayona Sáez et al. 2007).

Some studies have explored the university-industry knowledge transfer in UICs (e.g. Giuliani and Arza, 2009; Sherwood and Covin, 2008; Arvanitis et al., 2008; Acworth, 2008; Yusuf, 2008; Siegel et al., 2004; Fischer and Varga, 2003). These empirical studies have provided evidence that greater inputs from university or industry generate a higher propensity of UIC formation and a better UIC performance, such as a regional economic performance (e.g. Mueller, 2006), firm's R&D productivity (e.g. Baba et al., 2009; Kodama, 2008; Motohashi, 2005; Rothaermel and Thursby, 2005), and university's R&D productivity (e.g. Macho-Stadler et al., 2007; Chang et al., 2006; Numprasertch and Igel, 2005; Owen-Smith and Powell, 2003).

2.3.2.1 Industrial Studies

As for firms' collaboration with external partners, the problem of a substantial overlap of knowledge resources may arise when cooperating with other firms, since these entities operate in the same industrial technology paradigm (Bercovitz and Feldman, 2007). Although the university partner shows a great deal of foundational research, it is also isolated from industrial competition, and thus, may provide a more unique know-how with a broad research base. Laursen and Salter (2004) explored the relationships between firms' strategies and the propensity of cooperating with universities. Their empirical survey of UK manufacturing firms found that firms with more R&D expenditure, which adopt "open" search strategies (using higher numbers of 15 possible knowledge sources for innovative activities, such as enterprises, suppliers, customers, competitors, consultants ...etc.), have more innovative activities based on basic R&D and do not directly or promptly aim to produce new products, are more likely than other firms to draw from universities. Tether and Tajar (2008) investigated firms which source knowledge activities for innovation, and identified the fact that firms use three types of knowledge providers: consultancies, private research organisations, and a public science-base (i.e., universities and the government research laboratories). They used the data of the European Community Innovation Survey, and found that firms use more UICs when they have a higher level of commitment to undertake R&D on a continuous basis and a higher level of openness to use a variety of knowledge providers.

Although the authors may not have used the term, "resource-based theory" or resources variables in their articles, these studies employed the concept of "resource" to examine the characteristics of industry-level and firm-level. For example, Bayona Sáez et al. (2002) investigated the reasons companies cooperate with universities and research centres, and examined the characteristics involved with UICs. The data of 747 Spanish firms' R&D projects revealed that firms' major reasons for entering a UIC is to gain access to research funds by participating in government-sponsored programmes for business research projects, and to gain access to the international knowledge network, while neglecting to consider undertaking more basic research to access innovative ideas. Bagchi-Sen (2007) investigated the strategic considerations of the U.S. biotechnology industry about innovation and commercialisation, and found that firms link with universities to obtain breakthroughs and early technologies, to access federal funds, and to enhance their credibility and reputation.

Veugelers and Cassiman (2005) examined the firm and industry characteristics conducive to cooperation with universities, and argued that firm size, own R&D, and internal know-how capabilities are drivers of R&D cooperation with universities, because they are the firm's absorptive capacity concept, which emphasises the need for internal technological capabilities to gain the optimum benefit from R&D cooperation. Using data from a Community Innovation Survey in Belgium, they found that large firms are more likely to be involved in cooperative agreements with universities when the firms have a larger scale, higher innovation costs, and foreign headquarters. Segarra-Blasco and Arauzo-Carod (2008) attempted to understand the sources of firms' innovation and found that UIC activities are closely linked with the characteristics of the firm. Their survey of Spanish firms showed that R&D cooperation with universities is related to the level of the firm's R&D expenditure and size. It is also related to firms which perform better in terms of both product and process innovation, and depends on whether or not the firm belongs to a group.

2.3.2.2 University Studies

With regard to research which explores UICs from a university perspective, several related studies have used a quantitative survey to explore university characteristics and UIC formation. For example, Numprasertch and Igel (2005) applied case studies to explore knowledge management by collaborating with three university research units in Thailand. They found that many Thai researchers establish their linkages with industry based on personal connections rather than organisational commitments. In addition, two of three research units indicated that they prefer to collaborate with industry over academic research units, because UICs can provide market knowledge and additional funding for research. Wu (2007) used a case study of two elite universities in Shanghai (Fudan University and Shanghai Jiaotong University) to understand UICs in China, and the findings suggested that universities' engagement with industry in China is shaped by a national innovation system and local policy, such as the policy toward investment priority for the university and the allowance to reward universities' commercialisation. By conducting 24 interviews in 4 universities in Taiwan, Horng and Hsueh (2005) explored how to improve the transfer of knowledge from universities to firms, and identified four key elements of efficiently transferring university scientific knowledge, including university rewards for university faculty involvement in UICs, university resources in the UIC process, TTO members with marketing experience and skills, and university flexibility. However, their findings still lack empirical evidence.

Welsh et al. (2008) argued that the purpose of university intellectual property policies is to improve licensing income, industrial relations, and governmental mandates. By conducting interviews with biological scientists in the U.S. region, the author found that scientists view UICs and university intellectual property policies in complex and conflicting ways. Although university scientists believe that UICs are valuable, working with industry may restrict communication among them. Azagra-Caro et al. (2006) differentiated "university faculty support for the objectives of a UIC" and "the degree of cooperation to take place". According to the results of a questionnaire survey of university faculties in the Valencia region, they found that support for the objectives of UICs is sensitive to university age, while actual R&D collaborative activities are sensitive to gender, discipline, commitment to R&D and university encouragement. Acworth (2008) employed a case study of Cambridge-MIT Institute in the UK and developed the Knowledge Integration Community model to understand the elements of UICs. The model comprises six components: research universities, industry, government, education, knowledge exchange, and innovation in knowledge exchange. The author explored the role of each element, and also discussed the importance of support mechanisms, organisational structure, and review processes for knowledge exchange.

Price et al. (2008) highlighted the role of TTOs, and examined the tools and techniques of university TTOs. Based on a case study of University of Kansas Medical Centre, they suggested the success characteristics for TTOs to improve university technology commercialisation are related to the inventor's assessment, intellectual property protection and strength, invention of product/service features, market characteristics, commercialisation strategy, and value to the University Medical Centre. Otherwise, Foltz et al. (2003) used university patent data, and found that agricultural college infrastructure (number of graduate students), quality of faculty (faculty salary and funding per faculty member), patent-orientated TTO (number of TTO staff) are important to the success of universities' agricultural biotechnology patenting.

Powers and McDougall (2005) argued that universities, similar to private business sector companies, also compete with other research institutions in seeking for research funds, star faculties, and top-quality students. Competition for these resources has become especially intense in the United States, with limited federal research budgets cannibalising each other's top faculties, and attempting to attract the brightest students with merit aid. Even the public universities in the United States have more competition for a reduced pool of state funds. The competition for research with reduced national funds has also become harsher in Taiwan, and this pushes the universities in Taiwan to collaborate with industrial partners to seek more resources. With the economic downturn, and governments in many countries tending to reduce the budget of the educational sector, there is a greater need for universities to collaborate with industry.

2.3.2.3 Industrial and University Resources

Some researchers have looked into both the university characteristics and industry characteristics of UICs. Mueller (2006) argued that knowledge flows from university to industry are a crucial element for regional economic growth because university knowledge can be exploited and transformed commercially into products. The author believes that the existing knowledge stock and the absorptive capacity of employees in firms and researchers in universities represent the ability to produce and exploit knowledge, and thus, improve economic growth. Their empirical results support the fact that capital intensity, labour, R&D ability in private industry, R&D ability in universities, industrial grants per researcher, and entrepreneurship (number of new ventures formed) facilitate the regional economic performance of UIC activities. Giuliani and Arza (2009) examined the factors which drive the formation of valuable UICs. From a combination of case-study and archival data from two wine clusters in Chile and Italy, they found that firm level variables, such as the firm's human resources and experimentation intensity, and university level variables, such as the university's scale, publications, and scientific quality of department, were related to UIC formation in the Chile sample. Eun et al. (2006) examined the evolution of university-run enterprises in China, and indicated that the internal resources of universities, absorptive capacity of firms, and existence of intermediary institutions are the basic determinants of university-run enterprises. Boardman and Ponomariov (2009) found that industry grants, the number of graduate students supported by grants, and university scientists affiliated with university research centres, are the major factors related to whether or not university researchers work with private companies.

2.3.3 Empirical Studies of Resources of University Spin-offs

Since the commercialisation of university research is becoming more important, university spin-off activities have gained more attention recently. A university spin-off firm is a specific collaborative form, which is considered to be the flagship of the commercialisation of university research, as well as a tangible accomplishment of the entrepreneurial vision of university research (Shane, 2004; O'Shea et al., 2005, Landry et al., 2006).

Spin-off companies often have a feature of resource deficiency, which is a major constraint on their development (Vohora et al., 2004). One source to acquire the necessary resources and additional resources is to leverage from the parent collaborative organisation, often with lower costs and with additional legitimacy and organisational knowledge (Leitch and Harrison, 2005). In the case of university spin-offs, the university can provide assistants for the formation of the business in the form of financial support, business advice and access to facilities (Shane, 2004; Leitch and Harrison, 2005), and the business partners can provide commercial skills to create ventures by commercialising technological assets which universities typically lack (Vohora et al., 2004). Vohora et al. (2004) examined the critical junctures in the development of university spin-offs with a case study of high-technology companies, and the results revealed that spin-off companies need to overcome opportunity recognition, entrepreneurial commitment, credibility and sustainability if they are to succeed.

Landry et al. (2006) drew on the RBT to examine why some university researchers are more likely to create spin-offs, and proposed that the more resources university researchers have, the more the likelihood of spin-off creations they can provoke. They used data from 1554 Canadian university researchers and found that university researchers' knowledge in the field of life sciences and computer sciences, novelty of research, personal experience, social capital, and the protection of intellectual property facilitate the creation of university spin-offs. Like entrepreneurs in private firms, university entrepreneurs also need to develop their own idiosyncratic resources and capabilities to create competitive advantage. Powers and McDougall (2005) explored the outcomes of university commercial activities, and proposed that a set of university resource inputs, including financial resources, human capital, institutional resources, and commercial resources might affect the creation of university spin-offs and newly-formed companies to which a university had previously licensed technology. They used the data from 120 U.S. universities, and demonstrated that industrial research funding, the quality of the university faculty, the age of university TTOs, and venture capital are significant predictors of the creation of spin-off companies and newly-formed companies which previously licensed technology from the university. Lockett and Wright (2005) extended the traditional RBT with a dynamic view to explore the creation of university spin-offs. They emphasised that not only resource stocks, but also developing capabilities and routines, influence the creation of university spin-off activities. Their survey of UK universities' TTOs showed that both the number of university spin-offs created and the number of equity investments in existing spin-offs are positively associated with intellectual property protection expenditure, business development capabilities, and the royalty regime of the university.

Similarly, O'Shea et al. (2005) attempted to understand why some universities are more successful in generating technology-based spin-off companies, and argued that resources and capabilities contribute to university spin-off outcomes, such as institutional resources, financial resources, human resources, and commercial recourses. Employing the data from U.S. universities, the results revealed that a historical dependency on a successful technology transfer, faculty quality, federal funding in chemistry/life science/computer science, industrial funding, and the size of the TTO were found to be predictors of university spin-off activity. O'Shea et al. (2007) further applied this concept and used the case of the Massachusetts Institute of Technology (MIT), a top spin-off generator in the U.S., to explore the factors which contribute to successful academic entrepreneurship. They indicated that MIT's success is due to its science and engineering base, quality research faculty, organisational support, such as its TTO, and organisational encouragement for entrepreneurship.

Beyond this, Leitch and Harrison (2005) looked at boosting the potential of university spin-offs in a longitudinal study of Queen's University in Belfast and TTOs. They found that TTOs are a key element of university spin-off commercialisation activities. Rothaermel and Thursby (2005) focused on the role of university-industry knowledge flows on the performance of an incubator firm. They proposed that knowledge flow factors, such as the university license and the incubator firm's absorptive capacity, enhance the knowledge flow between university and industry, and endow the incubator firm with a unique resource, which leads to a better performance of the incubator firm with respect to revenue failure, and remains in incubation. Using a sample of 79 incubator firms, they found that firms' absorptive capacity is important for incubator firm performance. **Table 2.5** illustrates studies of resources and university-industry collaboration.

Table 2.5 Studies of Resources and University-Industry Collaboration

Author (s)	Topic	Sample/ Methodology	Variable(s) (Independent →Dependent)	Key findings
Acworth (2008)	Knowledge Integration Community model	Cambridge -MIT Institute in UK, Case study	NA	This shows how Cambridge-MIT Institute offers a more effective approach to knowledge-sharing. It describes the functional components, support mechanisms, organisational structure, review processes and mechanisms for knowledge exchange.
Arranz & de Arroyabe (2007)	Governance structures in R&D networks	189 EU respondents (universities, non-profit institutions, firms), Questionnaire, Regression	Technological applicability of R&D networks → Governance forms	This proposes that governance forms (i.e. structural safeguards, cohesion and openness) are based on the technological applicability of R&D networks. It shows that the greater the technology applicability of R&D networks, the greater the importance of safeguard mechanisms, structural mechanisms, and cohesion, but the lower the importance of openness.

Table 2.5 Studies of Resources and University-Industry Collaboration*(Continued)*

Author (s)	Topic	Sample/ Methodology	Variable(s) (Independent ➔Dependent)	Key findings
Azagra-Caro et al. (2006)	Faculty support for the objectives of UIC versus R&D cooperation	872 faculties from five Valencia universities, Questionnaire, Descriptive analysis	University age, faculty, dedication to R&D, university encouragement, influence of UIC, instruments of cooperation➔ UIC, R&D cooperation	This argues that faulty support for the objectives of UIC should not be confused with the degree of R&D cooperation. It shows that the former is sensitive to university age, while the latter is sensitive to gender, discipline, commitment to R&D and university encouragement.
Bagchi-Sen (2007)	Strategic considerations for innovation and the commercialisation of biotechnology firms	142 US biotech firms (94 health firms, 48 non-human health firm), Questionnaires, Descriptive analysis	NA	This explores the considerations of biotech firms in terms of innovation and commercialisation. It also explores local resources for the biotech business, such as university research scientists and facilities, local availability of scientists, venture capital, and local government assistance for R&D and commercialisation.
Bayona Sáez et al. (2002)	Why companies cooperate with universities and research centres	747 R&D projects between 1994 -1996, Spanish firms	Undertake basic research, international knowledge networks, funding ➔ Firms cooperate with universities and research centres	This attempts to understand the reasons why companies cooperate with universities and research centres, and the characteristics of the relationship involved in this. It shows that cooperation with centres involves basic research, conducted under the sponsorship of different research and support schemes promoted by central and regional administrations.
Boardman & Ponomariov (2009)	Why university researchers work for private companies	1643 US university researchers, Questionnaire survey, Regression.	Industry grants, affiliation with research centre, number of collaborators and students funded, scientific values, gender, age, minority status➔ Likelihood of interacting with private companies	This finds that (1) university researchers' interaction with industry does not conflict with their academic activities (e.g. supporting graduate students and government-funded research); (2) scientists affiliated with university research centres are more likely to interact with the private sector, but not in an entrepreneurial capacity.
Eun et al. (2006)	Development of university -run enterprises in China	University-run enterprises in China	NA (Theoretical framework development)	This adopts the TCE and RBT to explain the evolution of university-run enterprises in China. Is suggests that the basic determinants are (1) internal resources of university, (2) absorptive capacity of firms (3) existence of intermediary institutions.
Foltz et al. (2003)	Patent production of university	Dynamic count data model	NA	This uses an econometric model to examine the factors for universities' agricultural biotechnology patenting success. It shows the importance of infrastructure, quality faculty, patent-orientated TTOs, and dynamic feedback effects on agricultural biotechnology patent production.

Table 2.5 Studies of Resources and University-Industry Collaboration*(Continued)*

Author (s)	Topic	Sample/ Methodology	Variable(s) (Independent →Dependent)	Key findings
Giuliani & Arza (2009)	UIC and knowledge diffusion in firms	73 firms (41 Italian firm, 32 Chilean firms) Wine industry, Interview	1. Firm's knowledge base, scientific quality of university department →UIC 2. Firm's knowledge base→Diffusing knowledge in a cluster	This explores the role of a firm's knowledge base (e.g. formal training of HR, experience of human resources in the field, firm's experimentation intensity) and the scientific quality of the university in the UIC. It suggests that not all UICs are equally helpful: some will inevitably diffuse the firm's knowledge into a cluster.
Landry et al. (2006)	Why university researchers create spin-offs	1554 Canadian university researchers, Logistical regression.	Assets (knowledge, financial, personal, social capital, and intellectual property) →University Spin-offs creation	This shows that university researchers' knowledge assets in life sciences/computer sciences, novelty of research, personal experience, social capital, and protection of intellectual property are positively related to the creation of university spin-offs.
Laursen & Salter (2004)	What types of firms use universities as a source of innovation?	6287 UK manufacturing firms, Data adopted from others' studies. Regression	Openness, R&D intensity, firm age, firm size → Propensity to cooperate with university	This paper examines the effects of firms' search strategies on the propensity to cooperate with universities. It shows that firms which adopt "open" search strategies and invest in R&D are more likely than other firms to draw from universities.
Lockett & Wright (2005)	Antecedents of the creation of university spin-off companies	48 Respondents of TTO, Questionnaires, Regression	University's resources and University's capabilities → Creation of university spin-offs	This explores the effects of a university's resources and capabilities on the creation of university spin-offs. It highlights the importance of resource stocks (technology to commercialise, expenditure on external IP advice, availability of TTO staff), but also the appropriate capabilities of technology transfer officers (technology transfer experience, business development, reward system) in spin-off companies.
Macho -Stadler et al. (2007)	The role of TTOs in university licensing	Economic Equation	NA	This explores the importance of a critical size for TTOs, as well as the fact that TTOs may tend to "shelve" research projects, which leads to fewer licensing agreements but higher valuable innovations being sold at higher prices.
McAdam et al. (2006)	Resources of university incubators	NA	NA	This reviews the existing literature of the university incubator business and applies a business process perspective to conceptualise the key resources in university incubators in university science parks: business support and social support (entrepreneurial networks).

Table 2.5 Studies of Resources and University-Industry Collaboration*(Continued)*

Author (s)	Topic	Sample/ Methodology	Variable(s) (Independent →Dependent)	Key findings
Moto-hashi (2005)	The role of new technology firms in UICs	Japanese firms, regression	NA	According to the data from a survey by the *Research Institute of Economy, Trade and Industry* in Japan, smaller firms achieve higher productivity than large firms through UICs. It appears that UICs play a strong role in reducing the dependency of Japan's system of innovation on in-house R&D conducted within large corporations.
Mueller (2006)	How entrepreneurship and UICs drive economic growth	Database (period of 1992–2002) regressions	Entrepreneurship (start-up rate), UIC (industrial grants per researcher), capital intensity, labour → Regional economic performance	This shows that regions with a higher level of entrepreneurships and UICs generate economic growth. It indicates that firms specifically prefer universities as research partners when they are concerned about the appropriateness of the results.
Numprasertch & Igel (2005)	Knowledge management through collaboration	Three university laboratories in Thailand, Case studies	NA	This shows that (1) collaboration provides more breadth and depth of research knowledge than pure in-house development; (2) trust and balanced mutual benefits among partners are the main factors to ensure successful research collaboration; (3) Information & Communication Technologies and storage technologies are essential tools for collaboration, but are insufficient for research project success.
O'Shea et al. (2005)	Academic entrepreneurship and university spin-off performance	Panel data of U.S. universities from 1980 to 2001, Regression	Institutional resources, financial resources, commercial and human resources → Number of spin-off companies	This indicates that the resources and capabilities attributed to university spin-off outcomes, such as institutional resources (history of spinning out technology-based companies), human capital (rating of a university's science and engineering departments), financial resources (industry-funded research, universities budge of science and engineering, federal funds), and commercial resources and humans (people resources dedicated to the technology transfer effort, university-affiliated incubator)
O'Shea et al. (2007)	Academic entrepreneurship of MIT	Massachusetts Institute of Technology (MIT), Case study	NA	This uses four dimensions of academic entrepreneurship (individual characteristics, organisational policies and structures, organisational culture, and the external environment) to explore spin-off activity at universities.
Price et al. (2008)	Improving university technology commercialisation by TTO	TTO of University of Kansas Medical Centre, Case study	NA	This categorises 31 success characteristics for TTO's invention assessment tool with 6 sections: inventor's assessment, IP protection, product/service features invention, market characteristics, commercialisation strategy, value to University of Kansas Medical Centre.

Table 2.5 Studies of Resources and University-Industry Collaboration*(Continued)*

Author (s)	Topic	Sample/ Methodology	Variable(s) (Independent ➔Dependent)	Key findings
Powers & McDougall (2005)	Effects of resources and university commercialisation activities	Multi-source data from 120 U.S. universities	Industry research funding, university faculty quality, age of TTO, university patent importance, venture capital ➔ University commercialisation activities	This draws on the effects of particular resource sets of two university commercialisation activities, a number of start-up companies, and an initial public offering with a technology license. It shows that a set of university finance, human capital, and organisational resources are significant predictors of one or both outcomes.
Reuer & Zollo (2005)	Termination outcomes of research alliances	145 alliance termination, Questionnaire, Ordered logit regression	Experience accumulation, alliance features ➔ Alliance termination outcome	This examines the effects of alliance experience accumulation (collaboration, technological, partner-specific) and alliance features (alliance scope, alliance type, alliance relevance, division of labour, equity) jointly shaping research alliances' termination outcomes. It shows that partner-specific experience, division of labour, and coordination committees are related to the alliance termination outcome. Moreover, the effect of partner-specific experience is greater non-equity alliances than for equity structures.
Segarra-Blasco & Arauzo-Carod (2008)	Sources of innovation and UIC	R&D cooperation of 4150 Spanish firms, Data of Community Innovation Survey between 1998–2000	R&D intensity, firm size, intramural R&D activities, public funding, product and process innovation, firms that belong to a group ➔ R&D cooperation	This identifies five types of partners for R&D cooperation agreements: firms which belong to the same group; customers and suppliers, competitors, universities, and public research centres. It finds that, with high R&D investment and larger size, high innovative activities cooperate more with external partners.
Stuart et al. (2007)	University–biotechnology–pharmaceutical alliance chains	429 biotech firms, Ordered logit regressions	1. R&D expenses, revenues, patent applications, prestige of affiliated scientists ➔ Upstream alliances 2. Upstream agreements ➔Downstream alliances	This examines 1330 upstream alliances (with public sector research institutions) and 4139 downstream alliances (commercialisation alliances with firms). It shows that firms with multiple in-licensing agreements are more likely to engage in a downstream alliance. However, the positive relationship between in-licenses and downstream alliances attenuates as firms mature. Furthermore, firms which are well-networked in the academic community are more successful in acquiring commercialisation rights to scientific discoveries in universities.

Table 2.5 Studies of Resources and University-Industry Collaboration*(Continued)*

Author (s)	Topic	Sample/ Methodology	Variable(s) (Independent →Dependent)	Key findings
Siegel et al.(2004)	Knowledge Transfer of UIC	98 interviews of 3 types of stakeholders at five U.S. research universities, Descriptive analysis	NA	This identifies three different stakeholders (i.e., university administrators, academic and industry scientists, business managers and entrepreneurs). It also identifies barriers of Knowledge Transfer of UICs: culture clashes, bureaucratic inflexibility, poorly designed reward systems, and ineffective management of university technology transfer offices.
Tether& Tajar (2008)	Sourcing knowledge for innovation with different organisation	3392 Respondents, Manufacturing and service firms, Regression analysis	Firm's openness, commitment to R&D, financial commitment to innovation, openness, external innovations →Engaging in specialist knowledge providers	This explores the information sources of specialist knowledge providers (e.g. consultancies, universities, private research organisations, and government research laboratories) in firms' innovative activities. It finds that, although service firms are more likely than manufacturers to use specialist knowledge providers, they are more likely to engage consultants, whilst their links with research-based organisations, including the public science-base, are weaker.
Vohora et al. (2004)	Development of university spin-off companies	High-tech firms, Case study	NA	This identifies four different critical junctures that spin-off companies need to overcome if they are to succeed: opportunity recognition, entrepreneurial commitment, credibility and sustainability.
Welsh et al. (2008)	Academic capitalism and UIC	84 scientists (Agricultural & biotech) at 9 US universities, Interviews	NA	This identifies 3 UIC characteristics (productivity-enhancing, scientific interaction, industry support) and 3 purposes of university intellectual property policies (licensing income, industrial relations, and governmental mandates). It finds that scientists view UICs and universities' intellectual property policies in complex, and often conflicting ways.
Wu (2007)	Institutional changes, policy changes, and UIC	2 elite universities in Shanghai, China, Case study	NA	This discusses institutional changes within universities and policy changes at local and national levels. It indicates that, as universities gain greater autonomy, they adopt distinctive approaches to commercialising academic research and managing industrial linkages.
Yusuf (2008)	Intermediaries of UIC Knowledge exchange	NA	NA	This discusses the role of four types of intermediaries which assist universities in transferring knowledge: specialised intermediary (e.g. university TTO), financial intermediary (e.g. venture capitalist). institutional intermediary (e.g. public agency), and general purpose intermediary (universities are the leaders in producing and disseminating knowledge)

2.4 Resource Factors of University-Industry Collaboration

Prior studies have investigated a wide range of resource factors and used a variety of methods to measure resources. Strategic alliance scholars have proposed a number of resource typologies, and this well-known classification includes: tangible resources and intangible resources (Grant, 1991); property-based and knowledge-based resources (Miller and Shamise, 1996); physical resources, human resources and organisational resources (Barney, 1991); financial resources, physical resources, human capital, and organisational resources (Barney, 1997); financial resources, physical resources, technological resources, and managerial resources (Das and Teng, 1998; Chen and Chen, 2003; Powers and McDougall, 2005).

Past UIC studies focused on resources which facilitate the creation of university spin-off companies. Powers and McDougall (2005) classified the resources of university spin-off activities into three categories: financial resources (i.e. industry research funding and venture capital), human capital (i.e. faculty quality), and organisational resources (i.e. the age of TTOs and the importance of university patent). O'Shea et al. (2005) investigated universities' resources to generate more technology-based spin-off companies. They identified four types of resources: financial resources (i.e. industry-funded research, universities' budget for science and engineering, federal funds), human resources (i.e. rating of universities' science and engineering departments, the number of post-doctoral staff and faculty), commercial recourses (i.e. people resources dedicated to the TTO effort, presence of a university-affiliated incubator), and institutional resources (i.e. history of spinning out technology-based companies). Similarly, Landry et al. (2006) examined the resources of university researchers to create spin-offs, and categorised the determinants as six types: financial assets (i.e. private funding and research partnership grant), knowledge assets (i.e. publication, research field, research projects which focus on users' needs, consultancy, novelty of research findings), intellectual property assets, personnel assets (i.e. experience and seniority) organisational assets (i.e. university size, research unit size, and teaching hours), and social capital assets (i.e. linkages between researchers and private firms, government departments, and university communication departments, such as media relations and public affairs).

Although previous studies have contributed to understanding the resources which influence UICs, several problems arise when applying the existing typologies. Firstly, most UIC studies focus on the resources of university spin-off activities, and there is a lack of studies which analyse the relationship between resources and other types of university-industry collaborative activities. Secondly, patents and publications are considered to be important academic knowledge outputs for industrial innovation when collaborating with universities, but few studies have examined the other types of knowledge resources of UICs. Thirdly, TTOs, alliance experience, and organisational support play crucial roles in connecting university scientists and business entrepreneurs, but only a few studies employ the RBT to examine the relationship between organisational resources, UIC formation, and UIC performance. Fourthly, social resources are important in creating and maintaining an alliance, yet few studies have explored their impact on UIC contexts. Finally, conventional studies usually focus on the unilateral sources of universities or firms, but lack exploration of the resource profile between a university and firm.

Based on the RBT and contemporary studies about the determinant factors of UICs, 11 resource factors are identified in this study, and categorised into five groups of resources according to their characteristics: property-based resources, knowledge resources, relationship resources, organisational resources, and TTO resources. This study has contributed to (1) exploring the resource sets of both universities and industry respectively, (2) in-depth discussions about the knowledge resources of UICs, (3) extending alliance studies to discuss the alliance experience of UICs, since although alliance experience is widely discussed in inter-firm alliances, few authors have explored it in UIC studies (4) extending alliance studies and further discussing their role in UICs' social networks and trust, which are also widely discussed in inter-firm alliances, although few studies have explored them in UIC studies. Property-based resources, knowledge resources, organisational resources, and TTO resources are discussed below, while relationship resources will be further discussed separately in section 2.6.

2.4.1 Property-based resources

2.4.1.1 Industry Property-based resources

Property-based resources refer to financial resources and physical resources in this study. Industry funding enables universities to conduct more research, promote R&D development, and utilise their human capital to generate more commercially-feasible technologies (Yusuf, 2008). Several studies have found that industry funding improves university researchers' productivity. For example, university researchers in

Norway with industry grants showed better productivity in publishing and patents (Gulbrandsen and Smeby, 2005), while university researchers in Belgium with industry funding also demonstrated higher publication rates and more entrepreneurial activities (Van Looy et al., 2004).

With increasing competition among universities to gain access to the reduced pool of public funds (Powers and McDougall, 2005), universities have to seek industrial funding to conduct their research programmes. Industry funding has been found to facilitate the formation of university-industry R&D cooperation, especially in the case of university spin-off activities (e.g. Yusuf, 2008, Landry et al., 2006; De Coster and Butler, 2005; Powers and McDougall, 2005). Having conducted a survey of 200 academic researchers and 66 firms in seven industries, Mansfield (1995) found that, in the early stage of the development of a project, university researchers usually acquire more government funding than industrial funding. As the project matures, industrial financial support begins to grow in importance because the project becomes a commercial product.

2.4.1.2 University Property-based resources

On the other hand, Bagchi-Sen (2007) investigated the strategic considerations for US biotech firms collaborating with universities, and found that obtaining technologies and gaining access to federal funds are important motivations for a biotech firm to link with a university. This shows that university funding also provides an incentive for a firm to connect with a university. However, relatively few studies have examined the impact of university funding on UICs. Motohashi (2005) used data from the *Research Institute of Economy, Trade and Industry* in Japan and found that smaller firms achieve higher productivity through UICs than large firms. SMEs particularly need to collaborate with universities to access R&D funding due to their resource constraints (McAdam et al., 2006). Firms are more attracted to connecting with universities which have more public funding, research funding, or research facilities, to exploit the university resources and reduce innovation costs.

2.4.2 Knowledge Resources

2.4.2.1 University Knowledge Resources

To obtain technology, knowledge and human resources which complement those of the firm have been identified as a being critical reason for a firm to link with a university (Scott et al., 2002; Geisler and Rubenstein, 1989; Powers McDougall, 2005; Bayona Sáez et al., 2002). The new knowledge generated by university research may provide an important breakthrough for the firm's innovation (Rosenberg and Nelson, 1994; Bercovitz and Feldman, 2007). Very often in a UIC, the university is the source of the technology, and the firm is the technology recipient (Østergaard, 2008). Most researchers agree that collaboration with universities and research centres focuses on basic, generic, or pre-competitive research (Bayona Sáez et al., 2002). Bagchi-Sen (2007) found that 57% of the respondents of US biotech firms rate obtaining "breakthrough technologies or early technologies" as being the most important consideration when associating with university scientists. University knowledge resources have been found to facilitate UIC activities, such as the quality of the university (e.g. Tornquist and Kallsen, 1994), the quality of the university research and staff (Bruno and Orsenigo, 2003), and the scientific quality of the university departments (Giuliani and Arza, 2009).

However, some scholars have found that the relationship between university knowledge and the formation of a UIC is varied according to different contexts. For example, Giuliani and Arza (2009) suggest that, in Chile, the probability of forming a UIC increases with a higher level of strength of the scientific quality of universities (i.e. the average number of citations received by publications). However, the results are opposite in Italy. They found that the pattern of UICs is different in Chile and Italy. The linkage pattern in Chile is more selective, so that the best firms are connected to the best universities, further giving rise to valuable UICs (it is easier to diffuse knowledge to clusters), whereas the linkage pattern in Italy is more general, irrespective of the quality of the university's knowledge and the firm's knowledge, thus resulting in many non-valuable UICs. Mansfield and Lee (1996) found that top U.S. universities have significant linkages with industry because the firms believe that a UIC can boost the development of new technologies, products and processes, whereas second tier universities have significant interactions with industry because of the geographic motivation that firms can apply R&D to nearby universities. Similarly, D'Este and Fontana (2007) found that both highly and poorly-rated university departments in the UK engage in more UICs. While high quality departments provide basic research for industry, lower quality departments with less public funding provide applied research for industry to access industrial funding. These results are consistent with the finding that researchers in low quality departments are more involved in consultancy services for industry under funding pressures (Arocena and Sutz, 2005; Kruss, 2006; Vega-Jurado et al., 2007, Giuliani and Arza, 2009).

2.4.2.2 Industry Knowledge Resources

On the other hand, few previous studies examined the role of the firm's knowledge in UIC activities. Researchers have recently noticed that universities also look to obtain industrial knowledge, such as practical experience, possibilities of application, and additional insights (Arvanitis et al., 2008), industry's intellectual property and industrial new knowledge (Welsh et al., 2008). Giuliani and Arza (2009) adopted the definition of a knowledge base from Dosi (1988): *"a set of information inputs, knowledge and capabilities that inventors draw on when looking for innovative solutions"*. They identified three dimensions of a firm's knowledge base, including (i) firm's experimentation intensity, referring to the number of areas in which experimentation occurs; (ii) formal training of human resources, representing a firm's skilled knowledge workers based on their degree of education; (iii) experience of human resources in the field, representing the work experience of the employees. Their empirical results demonstrated that Chilean wine firms with a strong knowledge base have more linkages with universities and other public research organisations, because when firms have stronger knowledge resources, they have a stronger absorptive capacity to search and exploit valuable external knowledge (Cohen and Levinthal, 1990; Giuliani and Arza, 2009). However, the results showed that there is no significant relationship between Italian wine firms' knowledge base and these linkages.

2.4.2.3 Knowledge Resource Factors

Gonard (1999) suggests that firms need universities for two types of knowledge, including "basic knowledge", such as generic information which universities are able to offer, and "specific knowledge" such as knowledge focusing on problem-solving. According to technology management literature, technological activities can be classified according to their applicability (Brockhoff, 1992; Sakakibara; 1997; Trott, 2008; Arranz and de Arroyabe, 2007). Technology applicability refers to *the immediacy and speed of use or market acceptance of a technology* and technology ranges from generic activities with low applicability to those which generate products with an immediate application (Arranz and de Arroyabe, 2007). This thesis extends the classification and identifies three dimensions of knowledge resources according to the features of knowledge: basic science knowledge, applied science knowledge, and human capital.

Table 2.6 Dimensions of Knowledge Resources

	Tacit Type	Explicit Type	
		Quantity	Quality
Science Knowledge	Knowledge for dealing with existing technology or developing new technology, such as developing "early" or "breakthrough" technologies	Publication (including journals, books, reports. .etc)	Publications citation
Applied Knowledge	Knowledge of the commercialisation of R&D (e.g. Patent experience)	Patents, licensing	Patent citation
Human Capital	Experience, credibility, and reputation of research faculty	Number of research faculties	Educational level

Source: The Author

Table 2.6 illustrates three dimensions of knowledge resources. Basic science knowledge refers to pure science knowledge with a lower applicability. Applied science knowledge refers to applied science knowledge with high applicability. Human capital refers to the set of skills and knowledge embedded in researchers and staff, which are acquired from jobs, education, training and experience. Each type of knowledge resource involves tacit and explicit knowledge. Tacit knowledge cannot be codified, but can only be transmitted via training, or gained through personal experience.

2.4.3 Organisational resources

Technology is only one part of the business process (McAdam et al., 2006), which also involves complex systems, including resources, facilities, cultures, support mechanisms, and policies (O'Shea et al., 2007, Acworth, 2008). Organisational resources refer to assets or systems which are owned and controlled by an organisation (Barney 1991). Powers and McDougall (2005) examined the resources of university spin-off creation, and used the age of the TTOs and the importance of university patents (similar to patent citation counts, but measured by the impact of patents on future innovation across a range of patent fields) to be proxies of organisational resources. Based on data from U.S. universities, they found that the age of the TTOs was a significant predictor of the creation of spin-off and newly-formed companies. However, a university's patent portfolio did not prove to be a predictive indicator of university spin-offs and new companies. Similarly, Landry et al. (2006) investigated the resources of university spin-off creation and used the university size, laboratory size, and teaching hours as indicators of organisational assets. Their survey of a Canadian university showed that university size and laboratory size are positively related to spin-off creation, but the number of teaching hours per week has no significant relationship to spin-off creation.

Different from the definition of organisational resources by (Barney 1991), which may be confused with other types of resources which are also owned and controlled by an organisation, the different from the concept of organisational resources by Powers and McDougall (2005) and Landry et al. (2006), which is more related to property-based resources and knowledge resources, the organisational resources in this study highlight the intangible resources which enable the organisation to provide a well-organised system to support a UIC and facilitate knowledge transfer between university and industry. Based on previous research, experience of alliance and knowledge transfer, business/university support (Acworth, 2008; McAdam et al. 2006; Azagra-Caro et al., 2006), university experience (O'Shea et al., 2005; Azagra-Caro et al., 2006), university reward system (Lockett and Wright, 2005; Horng and Hsueh, 2005; Siegel et al., 2004), organisational structure and system (Boardman and Ponomariov, 2009; Sherwood and Covin, 2008; Acworth, 2008; Yusuf, 2008; Eun et al., 2006; Foltz et al., 2003), organisational orientation (Tether and Tajar, 2008; Arvanitis et al., 2008), and university policy (Arvanitis et al., 2008; Acworth, 2008; Wu, 2007) are the factors related to a UIC which are within the scope of "organisational resources" in this study. This thesis draws attention to alliance experience, organisational support, and a reward system, which enable an organisation to provide a well-organised platform to facilitate a UIC and knowledge transfer activities.

2.4.3.1 Industry Organisational resources

A firm's competency in interacting with clients, suppliers, and alliance partners has been found to be a key factor which can determine its business boundaries (Araujo et al., 2003; Kasch and Dowling, 2008). The experience of cooperating with other companies increases a firm's capability to manage the alliance (Kale et al., 2002), because a firm with alliance experience is more likely to recognise and understand its partner's knowledge pertaining to technology, to recognise collaborative possibilities, and to know how to successfully manage the alliance (Kale et al., 2002; Lane and Lubatkin, 1998; Mowery et al. 1996; Sherwood and Covin, 2008). In addition, firms with alliance experience are also found to be more likely to enter a new alliance because they have built up routines to reduce uncertainty and protect knowledge in interaction with other companies (Gulati, 1999; Katila and Mang, 2003).

Reuer and Zollo (2005) investigated the factors which shape the outcome of research alliances and proposed that the accumulated experience of alliance (i.e. collaboration experience, technological experience, partner-specific experience) and alliance features (i.e. alliance scope, alliance type, alliance relevance) jointly shape the outcome of the research alliance. They used a sample of 145 inter-firm terminated alliances of biotech and pharmaceutical firms, and found that 15% of alliances were successful, 34% were failures, and 51% experienced contract expiration or unilateral withdrawal by a partner. In addition, they found that research alliance outcomes are mainly influenced by alliance partners with the same experience, rather than general collaborative experience and technological experience. Sherwood & Covin (2008) examined the effect of experience factors (alliance experience, technology familiarity, and partner familiarity) on the successful acquisition of UIC knowledge. Using a sample of 104 industry managers, the results showed that partner familiarity is the major predictor of both tacit and explicit knowledge acquisition success in UICs.

Moreover, Lee (1996) indicated that organisational support for the UIC is a necessary condition to achieve UIC formation. McAdam et al. (2006) reviewed existing literature of university spin-off companies, and applied a business process perspective to conceptualise the resources in university spin-offs, namely business support and social support (entrepreneurial networks). They argued that identifying and providing business support for university spin-offs according to their needs (such as stage in the lifecycle, type of industry), and exploring available entrepreneurial networks for university spin-offs in the local environmental advance business processes and knowledge transfer activities in the commercialisation of intellectual property in university spin-offs. However, there is still a lack of evidence of the impact of business support on UICs.

2.4.3.2 University Organisational resources

A university's experience of connecting with industries and dealing with feedback from industries increases its capability to evaluate invention disclosures and technology transfer (Owen-Smith and Powell, 2003). Owen-Smith and Powell (2003) assessed the importance of technology transfer experience to university patenting in life sciences, and the patent data from 89 U.S. universities revealed that technology transfer experience (the number of years of issuing life science patents and the number of staff dedicated to technology transfer activities) improves the patent performance of universities. In addition, Lockett and Wright (2005) proposed that a university's experienced resources in spin-offs facilitates the creation of spin-offs, because spin-off experience improves the efficiency of managers, and leads to the generation of excess managerial resources which can be used to further facilitate the process. However, their findings indicate that, for university spin-offs in the UK, experienced resources in terms of the number of years of involvement with technology transfer do not appear to be an important predictor of spin-off creation. On the other hand, O'Shea et al. (2005) investigated the reason why some universities are more successful than others in generating spin-off companies, and the results revealed that university researchers' previous experience of technology transfer is positively related to spin-off formation.

O'Shea et al. (2007) applied a case study to explore the importance of academic entrepreneurship to MITs, and indicated that MITs' success is based on organisational support and organisational encouragement for entrepreneurship. Acworth (2008) employed a Knowledge Integration Community model of Cambridge-MIT Institute, established by the UK government to improve knowledge exchange. The author also indicated that supporting organisational mechanisms and review processes is important for knowledge exchange. Azagra-Caro et al. (2006) argued that university faculty involvement in UICs is related to university support, but they questioned whether faulty support for the objectives of UICs is a sufficient condition for university-industry R&D cooperation.

University reward is another organisational factor of UICs. In a US survey, 31.6% of business managers, 60.0% of TTO administrators, and 70.0% of university scientists agreed that the poorly designed reward systems of universities are a barrier to university-industry technology transfer (Siegel et al., 2004). When interviewing representatives of 4 universities in Taiwan, Horng and Hsueh (2005) found that universities providing greater rewards for faculty involvement in technology transfer generate more licenses. In addition, they indicated that insufficient rewards for Taiwanese university researchers to engage is a key barrier to an effective university-industry knowledge transfer, because the university system of promotion and tenure decisions in Taiwan are exclusively based on publications and federal research grants, with no weight placed on patents and industry partnerships.

2.4.4 Technology Transfer Office resources

Technology Transfer Offices (TTOs) are specific university resources to improve university-industry interaction. The technology transfer and cooperation patterns of UICs are more complex and dynamic than in an inter-firms setting, because multiple stakeholders are involved in a UIC, including university scientists, firms and TTOs. Siegel et al. (2003a, 2003b) and McAdam et al. (2006) indicated that these stakeholders have different perspectives, motives, and actions related to technology transfer. The main differences between stakeholders is that university scientists focus on the scientific discovery of new knowledge; entrepreneurs look for financial gain, and TTOs make an effort to promote and protect universities' intellectual property. (Shown as **Table 2.7**) Having conducted 98 interviews at U.S. research universities, Siegel et al. (2003a, 2003b) found that the perception of TTOs is different among stakeholders. For example, 55% of business managers and 25% of university researchers declared that poor marketing, technical knowledge, and negotiation skills of TTOs were key barriers for them in terms of knowledge transfer, whereas only 13% of TTO respondents considered that they were lacking in these areas.

Table 2.7 Stakeholders of Universities-Industry Technology Transfer

Stakeholder	Actions	Primary motive(s)	Secondary motive(s)	Perspective
University Scientist	Discovery of new knowledge	Recognition within the Scientific community: publications, grants, etc.	Financial gain and a desire to secure more funding (mainly for Graduate students & lab equipment)	Scientific
Technology Transfer Office	Works with faculty members and firms	Protect and market the universities intellectual property	Facilitate tech. diffusion and secure more research funding	Bureaucratic
Firm/ Entrepreneur	Commercialises new university-based technology	Financial gain	Maintain control of proprietary technologies	Organic/ent repreneurial

Source: Siegel et al. (2003a, 2003b).

Academic scientists are usually not good at evaluating the commercial value and opportunities for their inventions (Lockett et al., 2003, Lockett and Wright, 2005). In addition, university scientists normally have a high degree of psychological ownership of their inventions, but know relatively little about the market value and business process to commercialise them (O'Shea et al., 2005). Hence, TTOs represent specialised intermediaries to promote technology transfer and licensing activities between universities and industries to commercialise the inventions and manage intellectual property issues. TTOs are particularly important in traditionally non-commercial university environments, and they have been identified as being key commercial resources of UICs (Lockett and Wright, 2005; Powers and McDougall, 2005; O'Shea et al., 2005; O'Shea et al. 2007; Macho-Stadler et al., 2007). Rather than waiting for requests for licenses from firms, TTOs encourage university faculties to disclose their inventions promptly, seek research with a commercial potential, and then speedily evaluate the market value of those inventions, obtain protection of intellectual property via patenting, and then help to find a buyer and assist the transfer of knowledge to commercial users (O'Shea et al., 2007; Yusuf, 2008).

TTOs serve as a liaison between academic and business sectors with their role of "business coaching" and "stimulating entrepreneurial activity" TTO staff must understand the culture and function of both sectors (Siegel et al., 2004; Powers and McDougall, 2005; Lockett and Wright, 2005). For university researchers, TTOs are useful in saving their time and efforts in evaluating the commercial value of their research and commercialising their findings. For firms, TTOs provides a link to access university knowledge. TTOs are particularly a great help for SMEs to save costs and time on patenting and maintaining a patent over its lifetime (Yusuf, 2008).

Previous studies have elaborated the importance of TTOs in UICs (e.g. Siegel et al., 2004; McAdam et al., 2006; Yusuf, 2008; Macho-Stadler et al., 2007; Horng and Hsueh, 2005). TTO resources have been found to increase the creation of university spin-offs in several empirical studies. For example, Feldman et al. (2002) found that universities are more likely to use an equity approach to intellectual property transactions if their TTO is older. Powers and McDougall (2005) found that the age of the TTO (the number of years the office has had at least 0.5 full-time equivalent of dedicated professional staff) is a significant predictor of university spin-off and newly-formed companies in the U.S. region. Similarly, O'Shea et al. (2005) also provide convincing evidence in the U.S. region that the magnitude of resources invested in TTO personnel (the number of years the office has had full-time dedicated professional TTO staff) increases university spin-off activity. However, (Lockett and Wright, 2005) found that TTO resources (the number of full time employees working in the university's TTO) does not appear to be an important predictor of university spin-off creation in the UK region.

Although several articles have examined the relationship between TTO resources and university spin-off activities from a university-level perspective, there is a lack of studies exploring the impact of TTOs on firms' research productively from a firm-level perspective. Due to the different perception of the business sector toward TTO resources, it is necessary to a conduct a further study to obtain a deeper insight.

According to the resource classification developed in this study, literature which has examined the resource factors of UICs is listed in **Table 2.8**, and the details are described in **Appendix 4**.

Table 2.8 Studies which Examine the Resources of University-Industry Collaboration

Author (s) \ Resources	Property-based Resources		Knowledge Resources			Relationship Resources			Organisational Resources		TTO
	Physical	Financial Resources	Basic Science Knowledge	Applied Science Knowledge	Human Capital	Social Networks	Commit ment	Trust	Alliance Experience	Support and Reward	
Acworth (2008)										▲	
Arvanitis et al. (2008)				▲					▲		
Azagra-Caro et al. (2006)			▲		▲					▲	
Baba et al. (2009)					▲						
Bagchi-Sen (2007)	▲	▲			▲	▲					
Bayona Sáez et al. (2002)		▲	▲			▲					
Bercovitz & Feldman (2007)			▲	▲							
Boardman & Ponomariov (2009)		▲	▲	▲		▲	▲		▲		
Chang et al. (2006)				▲		▲				▲	
Chen and Lin (2004)							▲	▲			
Fischer & Varga (2003)		▲	▲								
Foltz et al. (2003)					▲						▲
Giuliani & Arza (2009)			▲		▲						
Horng & Hsueh (2005)										▲	▲
Kodama (2008)		▲									
Landry et al. (2006)	▲	▲	▲	▲	▲				▲		
Laursen & Salter (2004)		▲	▲	▲						▲	
Leitch & Harrison (2005)		▲	▲	▲	▲	▲				▲	
Li & Chen (2009)		▲	▲	▲					▲		
Lockett & Wright (2005)		▲	▲	▲					▲	▲	▲
Macho-Stadler et al. (2007)											▲

Table 2.8 Studies which Examine the Resources of University-Industry Collaboration *(Continued)*

Resources / Author (s)	Property-based Resources		Knowledge Resources			Relationship Resources			Organisational Resources		TTO
	Physical	Financial Resources	Basic Science Knowledge	Applied Science Knowledge	Human Capital	Social Networks	Com mitme nt	Trust	Alliance Experience	Support and Reward	
McAdam et al. (2006)						▲				▲	
Motohashi (2005)	▲										
Mueller (2006)		▲	▲	▲	▲					▲	
Numprasertch & Igel (2005)		▲					▲	▲			
O'Shea et al. (2005)		▲	▲						▲		▲
O'Shea et al. (2007)			▲		▲					▲	▲
Owen-Smith & Powell (2003)			▲	▲		▲			▲		
Østergaard (2008)						▲	▲	▲			
Powers & McDougall (2005)		▲		▲	▲					▲	▲
Price et al. (2008)			▲	▲					▲		
Rothaermel & Thursby (2005)			▲	▲							
Siegel et al. (2004)			▲	▲						▲	▲
Segarra-Blasco & Arauzo-Carod (2008)	▲	▲				▲					
Sherwood & Covin (2008)			▲	▲		▲			▲		
Stuart et al. (2007)						▲	▲				
Tether & Tajar (2008)						▲	▲				
van Rijnsoever et al. (2008)			▲	▲					▲		
Veugelers & Cassiman (2005)		▲	▲								
Wright et al. (2006)		▲									
Yusuf (2008)		▲		▲							▲

2.5 Transaction Cost Economics and University-Industry Collaboration

2.5.1 Transaction Cost Economics

Transaction Cost Economics (TCE) rests on the assumption that firms choose the activity which minimises its transaction costs from the various choices available. Transaction costs refer to costs which arise from activities necessary for an exchange, such as searching, drafting, and negotiating, monitoring, and enforcing contracts to insure against a partner's opportunistic behaviour. As an extension to establishing an alliance, firms choose a form of governance which minimises transaction costs by choosing different mechanisms, such as market governance, hierarchy governance, or hybrid governance (Williamson, 1975). In the case of outsourcing activities, firms will choose buying, internalisation, or alliance cooperation agreements.

The primary factors which cause transactional difficulties include transactional attributes, environmental attributes, and behavioural attributes (Williamson, 1981). Transactional attributes consist of asset specificity, uncertainty and complexity. Asset specificity refers to the difficulty with which an asset can be redeployed to alternative uses, while uncertainty relates to unanticipated changes in circumstances regarding a particular transaction, and complexity refers to the amount of different specialised input needed to complete a product or a service. Environmental attributes consist of small numbers bargaining and information impactedness. Small numbers bargaining refers to alternative sources of supply, so that the buyer is not completely dependent on any one source, while information impactedness refers to the information asymmetry between the two parties. Behavioural attributes comprise bounded rationality and opportunism. Bounded rationality refers to the difficulty of fully understanding the complexity of all possible decisions with the cognitive limitations of the human mind, and opportunism implies that decision makers act with guile and self-interest (Williamson, 1981; McIvor, 2009; Ke and Wei, 2007).

2.5.2 Transaction Cost Economics and Collaboration

According to Williamson (1981), the transactional difficulties lead to higher transaction costs, which further lead to more efficient vertical integration. TCE examines various aspects of inter-firm alliances, such as alliance formation (Yasuda, 2005; García-Canal et al., 2008; Kasch and Dowling, 2008), alliance performance (Nakos and Brouthers, 2008; Lui et al., 2009; Ybarra and Turk, 2009), governance modes (Chen and Chen, 2003; Yasuda, 2005), contractual coordination (Buvik and Haugland, 2005), technology and innovation sourcing decisions (Gooroochurn and Hanley, 2007; McIvor, 2009; van de Vrande et al., 2009), R&D cooperation development (Silipo, 2008; Okamuro, 2007), perceive risks of R&D cooperation (Helm and Kloyer, 2004), and termination outcomes of research alliances (Reuer and Zollo, 2005).

The TCE recommends firms to choose an organisational structure or governance which minimises the sum of the transaction costs. When this minimisation is achieved, firms choose to set up alliances, and when there are problems of moral hazard and adverse selection, an integrated and vertical form of cooperation occurs to minimise transaction costs (Williamson, 1981). Chen and Chen (2003) employed the TCE to interpret the governance structure of international strategic alliances undertaken by Taiwanese firms, and found that the TCE is powerful in explaining the choice between equity joint ventures and contractual alliances. Specifically, the asset specificity and behavioural uncertainty of partners prompts firms to seek more hierarchical control in strategic alliances and thus, they prefer equity joint ventures. In terms of the decision of firms to outsource innovation, heavy sunk costs in capital R&D expenditure signify that they may need to amortise these costs by producing innovation internally. A survey of the UK regions demonstrated that firms with high capital intensity and R&D intensity favour in-house process innovation rather than outsourcing. McIvor (2009) also applied the TCE in the case of outsourcing activities and argued that internalisation will be preferred if organisations have a higher potential of opportunism, and outsourcing activity is more likely to arise with a lower potential for opportunism. García-Canal et al. (2008) examined the influence of technological flows in the choice of joint ventures in technology alliances and found that joint ventures of technological alliances are necessary in situations in which the technological flow makes it difficult to monitor the activities of the alliance and distribute the profits. Silipo (2008) employed the TCE to explore the incentives and forms of R&D cooperation. Using an economic equilibrium equation analysis, the author illustrated that lower uncertainty (i.e. high probability of project success) and large spillover of the research results are the main factors which enhance the incentive to cooperate. In addition, their findings showed that firms usually prefer a research joint venture with shared costs and shared research results, and one which eliminates the duplication of effort.

On the other hand, when an alliance can achieve minimisation, firms will choose to participate in it. For example, where there are considerable costs and risks attached to R&D activities, or highly complex technological needs, the R&D cooperative agreements are preferred (Segarra-Blasco and Arauzo-Carod, 2008). Okamuro (2007) argues that the contractual form is important for firms to take full advantage of the cooperation by reducing transaction and coordination costs, preventing free-riding, and increasing the commitment of participants. Okamuro (2007) examined the effect of organisational characteristics and contractual characteristics on R&D collaboration, and data of Japanese manufacturing SMEs showed that R&D collaboration are more likely to succeed because of the "higher quality and quantity of external resources available through cooperation" and "lower transaction and coordination costs in a cooperative R&D"

Yasuda (2005) discussed the formalisation of technology-driven strategic alliances. He argued that joint ventures are preferred when their costs are lower than the cost of a stand-alone operation; technology licenses are preferred when they cost less than the cost incurred for their own development; joint R&D is preferred when the investment required for joint development and various administration costs is less than that required for their own in-house R&D; sourcing agreements are preferred when monetary compensation for licenses is lower than the costs incurred for a company's own development. However, the authors did not explore the decisions made among joint ventures, technology licenses, joint R&D, and sourcing agreements.

Although TCE has been applied to examine the antecedents of alliance choice, empirical research has not yet reached a clear conclusion. For example, asset specificity and closeness is found to be positively related to vertical integration (performing the activity internally within both organisations) in the hydroelectricity industry (Gulbrandsen et al., 2009). Conversely, Kasch & Dowling (2008) proposed that greater asset specificity and uncertainty leads to a higher level of integration in a commercialisation strategy for development, production and marketing. However, they did not find support for the influence of asset specificity, technological uncertainty, and market uncertainty on the level of integration in the commercialisation strategy of the development, production and marketing of young U.S. biotech firms. van de Vrande et al. (2009) examine the impacts of environmental turbulence, technological newness, technological distance, and prior cooperation, on the integrated level of technology sourcing governance. However, their results for the pharmaceutical industry showed that these factors did not have a significant influence on the choice among corporate venture capital investments, minority holdings, joint ventures and mergers and acquisitions. Lui et al. (2009) also found that the TCE argument, i.e. that greater asset specificity leads to a formal contract, and a greater formal contract leads to less opportunistic behaviour, was not evident in their survey of Hong Kong. They also suggested that formal contracts play a less important role in China. On the other hand, greater asset specificity and behavioural uncertainty of partners was found to lead firms to seek more hierarchical control in strategic alliances, but technological uncertainty was shown to be an insignificant factor in the choice between equity joint ventures and contractual alliances in a survey of Taiwan (Chen and Chen, 2003).

Ke & Wei (2007) extended the TCE to explore the factors which affect trading partners' knowledge-sharing. They proposed that a high level of asset specificity of sharing knowledge creates an increased requirement for a more integrated and safeguarded governance form to prevent a partner's opportunistic appropriation. Whereas a high level of partnership uncertainty leads to difficulty in judging whether or not a partner is faithfully sharing knowledge, measuring the quality of knowledge shared by the partner, rising ex-post control, and renegotiation and adaptation costs increase transaction costs, and therefore, impede the firm from sharing knowledge with the partner. However, the findings of a case study of 6 SMEs in the Singapore region illustrated that asset specificity did not play an important role in affecting the firm's knowledge-sharing decision. In addition, it was suggested that the effect of partnership uncertainty is attenuated by the focal firm's trust in the partner: given a high level of partnership uncertainty, a firm chooses to share knowledge when it trusts the partner. In contrast, different from the traditional TCE studies which assume that higher transaction costs lead to an integrated alliance, Segarra-Blasco & Arauzo-Carod (2008) assumed that cooperative R&D projects enable the costs and risks of R&D activities to be shared. They considered that cooperative R&D projects are more likely to occur when the cost and risk associated with R&D activities are substantial and the technological complexity in the sector is high. However, they did not count the case of integrated form, neither did they explain why their research variables (e.g. R&D intensity, firm size, internal Intramural R&D activities, public funding, firms which perform both product and process innovation) could be applied to be predictors of transaction costs.

2.5.3 Transaction Costs Economics and University-Industry Collaboration

Although transferring knowledge from university to industry has several advantages, the highly uncertain and non-codifiable nature of scientific knowledge generates high transaction costs for this know-how in the market. In addition, the R&D cooperation between universities and industry is characterised by high information asymmetry between partners, high transaction costs for knowledge exchange, and lower market benefits of the knowledge acquired (Veugelers and Cassiman, 2005). Bayona Sáez et al. (2002) found that cooperative R&D agreements undertaken by businesses, universities and research centres located in the same geographical area have a reduced risk of opportunism, and further, can improve the efficiency of the collaborative relationship. Chang et al. (2006) extend TCE logic to explain the invention disclosure behaviour of university researchers, and assume that researchers' choice of invention disclosure is made by evaluating the potential benefits and derivative costs. The benefits include licensing income, royalties, individual tenure application, and research project application. The costs include patent application fees, effort, and time for innovative invention.

Although collaboration with industry is an efficient way to disclose the commercial potential of researchers' innovative inventions, it also involves a higher level of risk and opportunistic behaviour. Landry and Amarar (1998) identified three types of collaborative research projects according to the objectives of university researchers: university–industry research collaboration, collaboration between researchers from other universities, and collaboration with other institutions (e.g. government agencies, local governments and organised interest groups). They found that collaboration with company representatives involves greater transaction costs due to the higher level of uncertainty, asset specificity, opportunistic behaviour, bounded rationality, and frequency.

Eun et al. (2006) employed TCE in the case of university-run enterprises, and assumed that universities are more likely to set up university-run enterprises, because of the higher level of external environmental opportunistic behaviour. When a firm has a lower absorptive capacity, or the intermediary institutions are still not well developed (e.g. IPR protection, related laws and regulations, etc.), the higher level of external opportunistic behaviour leads universities to choose a hierarchy form to facilitate knowledge flows between themselves and industrial firms. However, there is a lack of articles which examine university-industry cooperation governance with empirical data, and very few studies explore the effects of transaction costs on UICs and explore the choice of UIC governance from the perspective of firms.

2.5.4 Transaction Cost Factors of Collaboration

This thesis focuses on the role of transaction characteristics, such as asset specificity and uncertainty, since these are regarded as being the most critical factors leading to the choice of governance (Williamson, 1981; McIvor, 2009; Ke and Wei, 2007).

2.5.4.1 Asset Specificity

Asset specificity is the core determinant of the TCE, and it is the most frequently used variable in TCE studies. Asset specificity is defined as "*durable investments which are undertaken in support of particular transactions, the opportunity cost of which investments is much lower than best alternative use or by alternative users should the original transaction be prematurely terminated*" (Williamson, 1985). In other words, asset specificity is specifically designed for a particular transaction, and is hard to be redeployed for alternative use. According to the TCE, increasing asset specificity leads to a more highly safeguarded form of organisation, by minimising the contraction hazards caused by potential opportunistic exploitation of partners (Williamson, 1985). Williamson (1981, 1985) identifies four types of asset specificity: physical asset specificity (e.g. specialised facilities, systems, and tools), dedicated assets (e.g. investment for a specific partner), human asset specificity (e.g. highly specialised human skills), and site specificity (e.g. resources available at a certain location).

Asset specificity is identified as being the major factor leading to hierarchical governance (Williamson, 1981). According to the TCE, when one or both organisations make large transaction-specific investments, a quasi-rent of the hold-up problem arises (Klein et al., 1978; McIvor, 2009), and a moral hazard is generated. The firm contributing the greater level of the specific assets to the alliance runs the risk of opportunistic behaviour by the other party in the Williamsonian sense of "self-interest seeking with guile", and this is therefore likely to lead to the choice of an equity-based alliance (Chen and Chen, 2003).

Early cross-country and cross-industry studies found evidence to support Williamson's view that high asset specificity leads to hierarchical governance in terms of vertical integration (e.g., Joskow, 1988; Mahoney, 1992; Rindfleisch and

Heide, 1997; Shelanski and Klein, 1995; Clark et al., 1996). Chen and Chen (2003) also found that, when physical specificity and knowledge specificity (e.g. know-how) contribute to an alliance, Taiwanese firms are more likely to choose an equity-based alliance than a contract-based one. Gulbrandsen et al. (2009) argues that human assets are relevant to the mechanical maintenance services market, and their empirical survey of the EU's hydro-electricity industry demonstrates that human assets specificity has a positive effect on vertical integration to internalise an activity. Lui et al. (2009) argue that asset specificity has two major advantages, the first of which is that it facilitates the formation of a formal contact, which further reduces the opportunistic behaviour from the TCE perspective. The other is that asset specificity enhances trust, and further improves cooperative behaviour from the perspective of the social exchange theory. They analysed a sample of Hong Kong traders, which demonstrated that the predictions of the relational exchange theory are stronger than those of TCE.

In addition, evidence presented by Kasch and Dowling (2008) indicates that there is no significant relationship between asset specificity (e.g. the number of potential partners) and the level of integration of the biotech industry's commercialisation strategy when making a decision to exploit technology, either internally or externally. They infer that the insignificant results may have been due to a "number of potential partners" indirectly measuring the asset specificity. Although the effects of asset specificity on the integrated level of alliances is insignificant in the case of traders, with or with the inappropriate measurement, the effects of asset specificity will be stronger when the collaboration involves a greater amount of R&D investment in facilities, systems, tools, knowledge, and human resources.

2.5.4.2 Uncertainty

Uncertainty is defined as the focal firm's inability to predict a partner's behaviour and changes in the external environment (Joshi and Stump, 1999). Uncertainty increases transaction costs because of the greater level of negotiation required to continually align the contracts with environmental change (Williamson, 1991), and the greater level of contract writing to reduce opportunistic behaviour, such as partners clarifying contracts out of self-interest (Zaheer and Venkatraman, 1995). Thus, these higher transaction costs from uncertainty lead to hierarchical governance to overcome the difficulty of monitoring and supervision (Chen and Chen, 2003).

However, there is a lack of studies which examine the relationship of uncertainty and UIC governances, and empirical studies into the relationship between uncertainty and governance forms are, at best, inconclusive. Some studies find that the level of hierarchical governance will increase because of uncertainty (e.g. Kale and Puranam, 2004; Anderson and Schmittlein, 1984; Walker and Weber, 1987; Gulbrandsen et al., 2009; Anderson, 1985; Gatignon and Anderson, 1988; John and Weitz, 1988), whereas some do not find a significant relationship between uncertainty and hierarchical governance (e.g. Rindfleisch and Heide, 1997; White, 2000), and some even find that uncertainty has a negative effect on the level of hierarchical governance (e.g. Harrigan, 1986; van de Vrande et al., 2008; Steensma and Fairbank, 1999; Sutcliffe and Zaheer, 1998; Santoro and McGill, 2005). One of the reasons for these diverse results is the different definitions of uncertainty.

Williamson (1985) identifies two dimensions of uncertainty, namely, behavioural uncertainty and environmental uncertainty. Behavioural uncertainty in an alliance is defined as being *"the difficulty of observing and measuring adherence to the contractual arrangements by the transacting parties and the difficulty of measuring the performance of those parties"* (Chen and Chen, 2003). Environmental uncertainty originally refers to unpredictable external changes (Walker and Weber, 1984) and can be further differentiated as technological uncertainty and market uncertainty (Chakravarthy, 1985; Kasch and Dowling, 2008; Cavusgil and Lee, 2006), which represent unexpected changes in technologies and markets respectively (Chen and Chen, 2003; Kasch and Dowling, 2008). Otherwise, van de Vrande et al. (2009) and Folta (1998) group uncertainty as two types according to the level of influence exerted by firms' actions: exogenous uncertainty, which is largely un-affected by firms' actions, and endogenous uncertainty, which is. Exogenous uncertainty is determined by environmental factors and technological factors, whereas endogenous uncertainty usually arises from dissimilarities among partners, caused by different knowledge bases, or lack of prior cooperation to overcome information asymmetries (van de Vrande et al., 2009). The literature of transaction costs and collaboration are summarised in **Table 2.9**.

Table 2.9 Studies of Transaction Cost Economics and Collaboration

Author (s)	Topic	Sample/ Metho-dology	Variables (Independent →Dependent)	Key findings
Cavusgil & Lee (2008)	Factors which enhance alliance performance	184 managers of technology -intensive U.S. firms, Regression	Governance (contract-based, relation-based) → Alliance performance (strength, stability, knowledge acquisition)	This investigates the effect of governance on alliance performance. It shows that relation-based governance is more effective in strengthening an inter-firm partnership, stabilising the alliance, and facilitating knowledge transfer between alliance partners. The positive effects of relation-based governance are particularly enhanced under the high pressure of environmental turbulence.
García -Canal et al. (2008)	Technological flows and choice of joint ventures in technology alliances	Database of European Union from 1992 to 1999, Regression	Bilateral transfer of existing technology without undertaking R&D activities, Undertake R&D activities → Joint ventures v. s. contractual agreements	This uses the TCE and Economics of Intellectual Property Rights to examine the relationship between technological flow and joint venture technological alliances. It distinguishes technological flows as "bilateral transfers of existing technology without undertaking R&D activities" and "undertaking R&D activities (with existing technology owned by one partner, and a combination of existing technologies, without having their own technologies)". This shows that joint ventures which already have technologies combined and those which try to conduct joint R&D without starting from specific partners' previous technologies are preferred.
Gooroochurn & Hanley (2007)	Transaction costs and property rights in innovation outsourcing	8000 firms, Data from UK Community Innovation Survey, Regression	Transaction costs (capital intensity, R&D intensity), property rights (importance of protecting innovation with a formal agreement/ lead time/ secrecy) → Innovation outsourcing	This investigates the effect of transaction costs (TC) and property rights (PR), and factors of innovation outsourcing (process innovation, product innovation), and finds that (1) PR factors dominate TC factors (2) TC factors are more important for process innovation, while PR factors are more important for product innovation. (3) firms involved in process innovation have a higher probability of outsourcing innovation than firms involved in product innovation.
Ke & Wei (2007)	Factors affecting trading partners' knowledge-sharing	Data collected from 6 SMEs in Singapore, Case study	TCE factors (asset specificity, uncertainty), socio-political factors (power, interdependency, trust) → Trading partners' knowledge- sharing	This shows that socio-political factors are more robust in affecting whether or not a firm shares knowledge with a particular partner. Trust in the partner and the partner's power is particularly primary factors leading to knowledge-sharing ties. In contrast, asset specificity does not play an important role in affecting a firm's knowledge-sharing decision.

Table 2.9 Studies of Transaction Cost Economics and Collaboration *(Continued)*

Author (s)	Topic	Sample/ Metho-dology	Variables (Independent →Dependent)	Key findings
Landry & Amarar (1998)	Transaction costs and structure of collaborative academic research	1566 faculty members at 18 Canadian universities, Questionnaire survey, Regression	Publication assets, coordination costs, frequency of transactions, additional funding, additional publications, costs incurred, discipline → Structure of research projects (Teams/ institutes/ outside structures)	This shows that publication assets, coordination costs, additional funding, and disciplines affect university researchers' choice of institutional structures of collaborative research projects. On the other hand, the number of years researchers have been involved in collaborative research, additional publications, the importance of administrative burdens, and the time required to coordinate collaborative research, are shown to be unimportant in explaining these choices.
Lui et al. (2009)	Asset specificity roles in inter-firm cooperation	311 Hong Kong traders, Questionnaire survey, SEM analysis	TCE factors (asset specificity, formal contact, opportunistic), relational exchange factors (asset specificity, trust, cooperative behaviour) →Alliance performance	This argues that, according to TCE logic, greater asset specificity leads to a formal contact, which reduces opportunism, and further improves partnership performance. According to the relational exchange theory, greater asset specificity promotes more trust, which improves cooperative behaviour, and further generates a better partnership performance. These results support the predictions of the relational exchange theory more than those of transaction cost economics.
Silipo (2008)	Incentives and forms of R&D cooperation	Economic Equilibrium Equation	NA	This examines the effect of uncertainty and spillovers on R&D cooperation, and finds that firms prefer a research joint venture, but because of transaction costs, moral hazards and adverse selection problems, other forms of R&D cooperation may occur (e.g. R&D activity coordination and cross-licensing)
van de Vrande et al. (2009)	Effect of uncertainty on governance mode, choice of sourcing technology	1,810 deals from 153 pharmaceutical firms, Dataset, Multinomial logit regression	Exogenous uncertainty (environmental turbulence, technological newness, Endogenous uncertainty (technological distance, prior cooperation) → Governance modes	This examines the effect of exogenous uncertainty and endogenous uncertainty on the governance choice for technology sourcing (equity v. s. non-equity). It shows that, under higher levels of environmental turbulence, companies need to remain flexible with non-equity alliances to deal with unforeseen contingencies. The effect of other uncertain variables is found to be partially related to governance modes.

2.5.5 Transaction Costs, Resource Dependency and Complementarity

2.5.5.1 Transaction Costs and Resource Dependency

Because organisations rely on finite resources, access to external resources is the key foundation of organisational competitive advantage (Casciaro and Piskorski, 2005; Johansson, 2008). The Resource Dependency Theory (RDT) assumes that all organisations must establish links with the outside world to obtain the necessary resources for business survival, and that resources and actions carried out by partners in cooperative agreements lead to dependency (Pfeffer and Salancik, 1978; Gray, 1985; Mora-Valentin et al., 2004).

Partners in inter-organisational linkages exchange resources and capabilities according to each other's needs. Pfeffer and Salancik (1978) employed the concept of power and emphasised that the power of an individual depends on controlling resources while linking with external units. They indicated that the party which holds the most critical resources needed by the other will obtain more influence and control over the organisation, and the level of dependency on particular resources is determined by the importance of those resources, their level of scarcity, and the competition between the organisations to control them. In other word when a focal firm's dependency on its partner is greater than the partner's dependency on it, the interdependency is asymmetric, and the partner has the power to control or influence the focal firm (Ke and Wei, 2007), while the greater volume of resources contributed by partners generates greater dependency (Mora-Valentin et al., 2004). Otherwise, when cooperating partners contribute equal resources which benefit them both, the two organisations are considered to be interdependent (Gulati, 1995a, 1995b; Mora-Valentin et al., 2004).

RDT is similar to TCE in exploring transaction-specific investments, uncertainty, and the use of contracts when firms link with other organisations. Different to TCE, which analyses the transaction costs of various governances and assumes that alliance is preferred because it minimises transaction costs among the choices of governance modes, RDT purposes that an alliance is formed to gain control of critical resources. RDT suggests that firms proactively seek control over resources to enhance their ability to create a competitive advantage (Pfeffer and Salancik, 1978). In other words, while TCE focuses on "efficiency" in minimising the cost of transaction actions through external exchange operations, RDT emphasises "effectiveness" in gaining access to important resources from other organisations in order to operate and survive.

Dependency on external resources is the key antecedent to motivate the establishment of an inter-firm relationship (Ke and Wei, 2007). As an organisation seeks resources from the outside world, its resource dependency rises, and RDT suggests that firms should manage this dependency by adopting strategies such as (1) using integration, merger and diversification to alter patterns of interdependency; (2) setting up collective structures to establish a negotiated environment, (3) using a political or social approach to form a created environment (Pfeffer and Salancik 1978). According to RBT logic, while partners are more capable of providing the resources firms need, partners are attracted to linking with firms in order to gain and exploit the partners' resources and create alliance opportunities. However, little empirical studies have been devoted to RDT. Buvik and Haugland (2005) explored the relationship between dependency and contractual coordination and argued that the allocation of specific assets (i.e. unilateral buyer-held, unilateral supplier-held, reciprocal) affects contractual coordination across buyer – seller relationships. Data from a survey of industrial purchasing relationships demonstrated that unilateral investments in specific assets by either the buyer or the supplier are more strongly supported by contractual coordination as the length of the relationship increases. However, mutual investment in specific assets is found to decrease the level of contractual coordination as the relationship develops over time, because a balanced dependency relationship which evolves over time may need more safeguards.

2.5.5.2 Resource Complementarity and Collaboration

Resource complementarity refers to a symmetric partnership which jointly uses two sets of resources to yield a higher total return (Chi, 1994). For instance, the acquisition of Beckman Instruments by SmithKline is a good example of resource complementarity. Through this acquisition, SmithKline gained diversification in diagnostic technology to strengthen its biomedical research capability, and Beckman gained strength in its pharmaceutical sales force for its products (Hitt et al. 1998). Resource complementarity has been identified as being an important factor in driving the formation of inter-firm alliances, and is found to create greater synergy of firms' performance (Hamel, 1991; Hill and Hellriegel, 1994; Shan et al. 1994; Chen and Chen, 2003; Harrigan, 1988; Kale et al., 2000; Lambe et al., 2002; Mowery et al., 1996; Saxton, 1997; Shenkar and Li, 1999). Bizan (2003) examined the determinants of success of international research alliances, and evidence from American-Israeli R&D projects demonstrates that the complementary abilities between the partners, the duration of the project, and ownership relation are predictors of the technical success of government-supported international research alliances. Moreover, the complementarity of partners' skills is found to be a determinant of a stable cooperation (Park and Ungson, 2001). Wiklund and Shepherd (2009) argue that resource complementarity does not necessarily generate value for alliances and acquisitions, because the extent to which the potential value becomes realised depends on the firm's ability to exploit and conduct productive resource combinations. A sample of 319 small firms shows that alliances and acquisitions bring limited benefits to firms unless effort is devoted to combining resources.

One of the most important reasons of the formation of alliance is that a firm can exchange complementary resources to create competitive advantage (Chen and Chang, 2004). A strategic alliance is the easiest way to find a party with symmetrical and complementary resources. Initially, the exchange contract will take the form of collaboration, and then more resources will be pooled as the partnership develops (Chen and Chen, 2003). In terms of SMEs, due to their limit of internal business resources, a cooperative R&D is an efficient way to gain superior and complementary external resources (Okamuro, 2007). The sharing of complementary resources among alliance partners enables parties to develop an idiosyncratic resource foundation, which makes synergy creation possible, and provides strong incentives to maintain the relationship (Lambe et al., 2002; Lin et al., 2009). Colombo et al. (2006) examined the commercial alliance of young Italian high-tech firms, which they observed between 1994 and 2003. The results of this economic analysis demonstrated that gaining access to a partner's respective specialised complementary assets is a key driver for young high-tech firms to set up exploitative commercial alliances, using partners' existing assets and capabilities by dividing tasks.

Chen and Chang (2004) argue that, if potential collaborative partners can provide valuable complementary resources, even if transaction costs are higher, as long as the total collaboration cost is lower than that of internalisation, a business network will emerge. Once this network has been formed, close interaction will gradually reduce TC over time, and increase the benefits of networking. López Iturriaga and Martín Cruz (2008) applied the idea of complementarity to cooperate spin-off activities and consider cooperate spin-offs is consequence of firms trying to exploit the complementarity among their resources (i.e. knowledge, diversification, and social networks). Using a sample of 3462 Spanish firms between 1992 and 2002, they found that spin-offs are more common among firms with intensive social network and more new knowledge.

Bayona Sáez et al. (2002) indicate that innovation is sometimes the result of R&D collaboration between different types of organisation (such as competitors, suppliers, and customers, or universities and research centres) with complementary resources. Sakakibara (2001) argues that cooperation between firms in the same industry can improve R&D efficiency by means of benefits of economies of scale, since firms are more able to acquire the necessary complementary resources from cross-industry cooperation. Veugelers and Cassiman (2005) used Belgium Community Innovation Survey data and found that cooperating with universities is complementary to a firm's innovation activities, such as performing own R&D, sourcing public information, and cooperating with other partners. Tether and Tajar (2008) found that firms are likely to use specialist knowledge providers, which tend to complement their own internal innovation activities, and complement other external sources of knowledge. While the researchers agree that complementary resources are an important motivation for firms to collaborate with universities, few articles have examined the impact of complementary resources and UIC formation. Literature of resource dependency, and resource complementarity and collaboration is summarised in **Table 2.10**, and TCE related determinants of collaboration are illustrated in **Table 2.11**.

Table 2.10 Studies of Resource Dependency, Complementarity and Collaboration

Author (s)	Topic	Sample/ Metho-dology	Variable(s) (Independent →Dependent)	Key findings
Buvik & Haugland (2005)	Effect of allocation of specific assets on contractual coordination	157 industrial purchasing relationships, Questionnaire survey	Allocation of specific assets (Unilateral buyer-held, Unilateral supplier-held, Reciprocal) → Contractual coordination	This shows that unilateral investments in specific assets by either the buyer or the supplier are strongly supported by contractual coordination. In addition, it finds that relationship duration plays as a moderator variable in this relationship: the effects of allocation of specific assets are stronger as the length of the relationship increases.
Chen & Chang (2004)	Dynamics of Business Network Embedded-ness	NA	NA	This explores the relationship between inter-firm characteristics and business network embeddedness. It suggests that firms utilise inter-firm specialisation, relational capital and routines to increase resource value, to reduce transaction costs, and to let business network become gradually embedded in an evolutionary process, which facilitates incremental innovation but hinders radical innovation.

Table 2.10 Studies of Resource Dependency, Complementarity and Collaboration *(Continued)*

Author (s)	Topic	Sample/ Metho-dology	Variables (Independent →Dependent)	Key findings
Colombo et al. (2006)	Complementary assets and alliance formation of high-tech start-ups	New high-tech firms, Data from 1994 to 2003	Firm size, prior innovation output, Sponsorship →Commercial alliances (exploitative commercial alliances/ explorative technological alliances)	This distinguishes exploitative commercial alliances and explorative technological alliances and examines the effects of complementary assets on the formation of two types of alliances. It is shown that "combination of specialised complementary assets" appears to be a key driver of exploitative commercial alliances. In addition, it suggests that there is an inverse U-shape that the propensity of exploitative commercial alliances will decrease when firm size increase.
Lin et al. (2009)	Resource complementarity, status association, and alliance performance	3498 alliances of 195 U.S., Hierarchical regression analysis	Resource complementarity, societal/network status, asymmetry in societal/network status→ Alliance performance (firm return on assets)	This suggests a joint consideration of resource complementarity and status effects (i.e. societal status and network status) are critical for understanding alliance formations and their effects on firm performance.
López Iturriaga & Martín Cruz (2008)	Antecedents of corporate spin-offs	Data from Spanish government corporate strategies survey	Social networks, knowledge investments, diversification →Lunching corporate spin-offs	This identifies three reasons for firms to engage in spin-offs: to create complementarities, to appropriate residual rents, and to focus on the core business. It finds that spin-offs are more common among firms with social network and new knowledge.
Mora-Valentin et al. (2004)	Determining factors in the success of UIC R&D agreements	800 cooperative agreements between Spanish firms and research organisations	Contextual factors and organisational factors → Success of agreement (global satisfaction, evolution of the relationship)	This analyses the impact of contextual factors (i.e. previous links, partners' reputation, definition of objectives, geographic proximity, institutionalisation) and organisational factors (i.e. commitment, communication, trust, conflict, dependency) in the success of UIC R&D agreements. It is shown that, in the case of firms, outstanding factors are previous links, definition of objectives, commitment, and conflict. Whereas for research organisations, previous links, the partners' reputation. communication, commitment, trust and are more relevant.
Wiklund & Shepherd (2009)	The role of resource combination activities in effectiveness of alliances and acquisitions	319 small firms, secondary questionnaire data	Resource complementarity (domestic firm, international firm)→ Engaging in domestic/ international alliances and acquisitions	This explores the effects of resource combination activities on alliances and acquisitions in domestic and international condition respectively. It is shown that alliances and acquisitions bring limited benefits to firms unless deliberate effort is devoted to resource combination

Table 2.11 Summary of Transaction Cost Factors and Collaboration

	AS	U	TC	O	RC	D	Hypotheses
Bayona Sáez et al. (2002)				▲			In the same geographical region → Decreasing opportunism
Buvik & Haugland (2005)	▲						Allocation of specific assets (unilateral buyer-held, unilateral supplier-held, reciprocal) → Contractual coordination
Chen & Chang (2004)			▲				NA
Chen & Chen (2003)	▲	▲			▲	▲	Assets specificity to alliance, technological uncertainty, behaviour uncertainty, resource complementarity → Choice between joint ventures and contractual alliances
Colombo et al. (2006)			▲				Firm size, Prior innovation output , VC-backed NTBFs, PRO-sponsored NTBFs → exploitative commercial alliance, explorative technological alliances
Gooroochurn & Hanley (2007)			▲				Firms incurring heavy sunk costs of capital and R&D favour in-house production of innovation.
Gulbrandsen et al. (2009)	▲						Asset Specificity→ Vertical Integration
Helm & Kloyer (2004)				▲			NA
Kasch & Dowling (2008)	▲	▲					Uncertainty, asset specificity →Commercial strategy (integration, bilateral cooperation, unilateral cooperation)
Lin (2006)			▲				(1) Information asymmetry, causal ambiguity → Information cost (2) Inimitability, Immobility→ coordination cost (3) Information cost, coordination cost→ Transaction modes→ value creation
Lui et al. (2009)	▲			▲			Asset specificity →Formal contact → Opportunistic behaviour → Partnership performance
McIvor (2009)				▲			NA
Nakos & Brouthers (2008)				▲			NA
Okamuro (2007)			▲	▲			Coordination cost (participants number, participants of different industries, firm size, participants from business partner, participants from research/university), trust and opportunism (familiar and experience) → Successful of cooperative R&D.
Silipo (2008)		▲					NA
van de Vrande et al. (2009)		▲					environmental turbulence, technological newness, technological distance, prior cooperation → Integrated governance modes
Veugelers & Cassiman (2005)			▲				Size, cost, risk, own R&D capacity (absorptive capacity), internal know-how capabilities, firms with foreign headquarters → UIC
Ybarra & Turk (2009)	▲					▲	Asset specificity, balanced asset specificity, interdependency → Alliance performance

Note: AS=Asset Specificity; U=Uncertainty; TC=Transaction Cost; O=Opportunism; RC=Resource Complementarity; D=Dependency

2.6 Social Exchange Theory, Relationship Resources, and Relational Governance

2.6.1 Social Exchange Theory and Social Capital

Although it is useful to analyse the economic activities from the perspective of economics, these activities are still on the base of social interaction, and the economic rational decision based on cost-benefit analysis might ignore the issue of social factors within the transaction (Granovetter, 1985). In reality, the alliance decision does not totally rely on the economic evaluation and economic analysis. Social exchange theory (SET), developed by Thibaut and Kelley (1986), suggested that the organisations have to exchange with others to obtain valuable and scarce resources in the social contexts, and the exchange are involved with negotiation between parties. SET posits that all relationships are formed by the use of a subjective cost-benefit analysis and the comparison of alternatives. Different to TCE which focuses on economic efficiency in exchange forms, SET argues that people and organisations may exchange under social benefits such as reciprocity, access reputation and influence on others, altruism and perception of efficacy (Thibaut and Kelley, 1986).

Social capital is about the value derived from being socially embedded in social networks which bonding and bridging between diverse people, and it resides in relationships created through exchanges and interactions (Dekker and Uslaner 2001). The social capital is constituted by trust, commitment, goodwill, reciprocity and benevolence (Kwon, 2008). Dekker and Uslaner (2001) posited that social capital is fundamentally about how people interact with each other. In contrast to the exchanges that based on objective economic value, the benefits from social exchanges are not often contracted explicitly (Das and Teng, 2002). Inter-organisational relationships may exist due to the social benefits, even if they are not cost-efficient (Ke and Wei, 2007).

According to the social exchange perspective, social capital plays an essential role in establishing, stabilising and maintaining a successful inter-firm relationship. Several empirical studies have found the evidence that social capital is beneficial for inter-firms relationships. For example, Lee (2007) examines the influence of alliances on SMEs performance. Investigating a sample of 189 Taiwanese biotech firms, the results show that alliance partners' relationship characteristics including trust, communication, coordination, and shared value have influence on SMEs firm performance in new ventures success. Nielsen (2005) used a sample of 118 international alliances of Danish firms to examine the factors determining international strategic alliance performance, and the findings support the importance of trust, complementarity, collaborative know-how, and less protectiveness in explaining international alliance success. Trust and protectiveness are especially found to highly related to performance variables. By testing on samples of SMEs in Caribbean region, Nakos and Brouthers (2008) find commitment improve SMEs international alliance performance, in addition, they find that while firms has greater perceived commitment, the greater process control generate higher alliance performance.

Kwon (2008) uses SET to examine antecedents and consequences of international joint venture partnerships, and the empirical results provide that evidence that trust and commitment contributes to joint venture performance in satisfaction and objectives achievement. In addition, they find the trust and commitment between Korean-Japanese joint ventures are higher than Korean- Western joint ventures. On the contrary, Okamuro (2007) examines the determinants of successful R&D cooperation in Japanese SMEs in manufacturing industry, and proposes that partner familiarity and R&D alliance experience increase trust and reduce the risk of partner opportunism and therefore the more successful of cooperative R&D projects. However, the findings show that familiarity and experience do not have a significant impact on the success of cooperative R&D projects. Lui et al. (2009) also find the evidence that trust facilitates cooperative behaviour and partnership performance. Using the sample of 311 Hong Kong traders, they find that greater asset specificity generate higher partnership performance because the asset specificity increase the trust and cooperative behaviour, their finding support the predictions of social exchange theory. Ybarra and Turk (2009) use TCE and SET to explore the antecedents and outcomes of trust between technology alliance partners and find that SET factors (i.e. duration, communication, shared values, relationship equity) provide a more thorough explanation of trust than TCE factors. The finds shows that social exchange factors contributes to the development of higher levels of trust, and which further generate shape alliance performance and learning from partner.

The social network is a type of social resources that allow people and organisation access to valuable resources. Eisenhardt and Schoonhoven (1996) found that the alliances are more likely to be formed when both firms are in vulnerable strategic positions or social positions. Moreover, the firms with multiple in-licensing agreements with university and public sector research institutions, namely upstream alliances, are found to be more likely to attract revenue-generating alliances with other firms, namely downstream alliances (Stuart et al., 2007). The social network is important for the formation of alliances, but it is not social capital that derived from the interactions or exchanges with the existing partner. Therefore, this thesis names the social-related factors as relationship resources that consist of social capital and social network.

2.6.2 Relationship Resources of University-Industry Collaboration

The firms with more social capital resources such as trust, familiarity, long-term commitment, and common understanding shows the evidences of developing university-industry relationships (Thune, 2007). Moreover, trust, commitment and integration are found to have positive impacts on the UIC performance (Plewa and Quester, 2007). The relationship resources also found to improve the university performance. Owen-Smith and Powell (2003) investigate the patent record of 89 U.S. universities and find that university involvements in biotech industry networks are positively related to the university' citation impact of life science patents.

In addition, the key challenge for a firm in knowledge seeking is to identify who to access and how to access (Tether and Tajar, 2008). The social capital and networking capabilities enhance firm ability to span boundaries, search and establish effective relationships with appropriate partners, engage with different communities that have their own institutional norms, and to seek, select and utilise partner knowledge (Tushman and Scanlan, 1981; Rosenkopf and Nerkar, 2001; Tether and Tajar, 2008). McAdam et al. (2006) apply a perspective of business process to examine UIC and argue that entrepreneurial networks and business support are key resources for the formation of university incubator in university science parks. The survey of R&D cooperation of Spanish firms show that the firms with more social networks (e.g. firms belonging to a group or a firm that establishes cooperation agreements with other partners, and firms belonging to domestic groups) are found to be more likely to establish cooperation R&D agreements with universities and public research centres (Segarra-Blasco and Arauzo-Carod, 2008). With the in-depth interviews with 45 R&D executives, Bercovitz and Feldman (2007) indicate that a firm can create close ties to a university through an alumni connection. In addition, when a firm has a strong connection with a particular university member, it is more likely to fund university research projects, licenses the resulting inventions. Tether and Tajar (2008) examined the factors affecting the linkages with specialist knowledge providers, such as universities and public research institutes, private research organisations, and consultants. They used the number of graduates as indicator of networking capabilities, because through employing graduates, especially science and engineering graduates, firm have more ability to recognise and utilise the relevant knowledge, and it will enable the firms to search for collaboration and form relationships with various specialist knowledge providers. Their survey of manufacture and service firms showed that firms with higher level of social capital, networking capabilities, and commitments to innovation are more likely to engage in the specialist knowledge providers to access information and knowledge, and firms with well networked in the academic community are more likely to have technology-access agreements with universities.

2.6.3 Relationship Resources and Knowledge Transfer

The relationship resources are applied to understand the knowledge exchange activities and found to enable partner to facilitate the knowledge flow and knowledge exchange (Dahl and Pedersen, 2004; Giuliani, 2007; Østergaard, 2008). For example, Numprasertch and Igel (2005) examined the R&D projects of three university laboratories in Thailand and concluded that trust and balanced mutual benefits among members are the main factors to ensure successful research collaboration. Chen and Lin (2004) analysed 137 alliances and the results showed that trust and adjustment between partners, explicitness of knowledge, and firm's absorptive capacity have positive and significant effects on knowledge transfer performance, such as acquiring the targeted knowledge and the acquisition knowledge contributes to the firm's technology development, new product development, human resource quality, and production efficiency. Ke and Wei (2007) employ TCE and social perspective to examine the determinants of knowledge exchange. With the case study of 6 SMEs in Singapore, they suggest that social-political factors (i.e. power, interdependency, trust) are more robust than TCE factors (i.e. asset specificity, uncertainty) in affecting whether a firm to share knowledge with a particular partner. Trust towards the partner and the partner's power particularly are primary factors leading firm's knowledge sharing decision. With the knowledge management perspective, relationship resources enable the collaborative partners to find key information possible, to enhance accessibility and transparency between the partners toward knowledge exchange activities, to share information, to facilitate the knowledge transfer and learning across the organisations, and to build new knowledge and capabilities, which lead to the creation of value and synergy (Doz and Hamel, 1998; Kale et al., 2000; Cavusgil and Lee, 2006; Philbin, 2008).

Regarding the collaboration with research institution, in the formation and development of alliances, external networks make firms contact with academic institutions to generate and exploit knowledge and even get more information of market (Yli-Renko et al., 2001, Philbin, 2008). In addition, firm can gather government information and industrial standards, and track what other firms in the sector are doing through UIC (Sakakibara, 1997; Bayona Sáez et al., 2002). The empirical evidences support the positive impacts of relationship resources on knowledge transfer between university and industry. Østergaard (2008) examines the informal contacts between employees and found employees with social network (e.g. educated at the local university, previously involved in projects with university research) are more able to acquire knowledge from informal contacts with university researchers. Sherwood and Covin (2008) propose that partner familiarity, partner trust, and technology familiarity are determinants of knowledge acquisition success in UIC and find that a firm gains more both tacit knowledge and explicit knowledge from university as the increases of the trust with the partner, and the communications between the partners' technology experts. However, partner trust predicts the successful acquisition of tacit knowledge but not explicit knowledge.

2.6.4 Social Exchange Theory and Relational governance

A well relationship plays an important role in setting up the linkages of the activities and resources, which can achieve the quality and successful outcomes between inter-firm interactions (Hakansson and Snehota, 1995, Cavusgil and Lee, 2006). TCE provides an economic perspective in determining the governance scope by analysing the transaction costs under the various choices available (Williamson, 1975). However, the alliances base upon the social processes, partially inter-organisational relationships which may exist even if they are not cost-efficient, and TCE cannot fully explain the alliance formations and exchange processes (Ke and Wei, 2007). The main difference between TCE and SET is that TCE focuses on the opportunistic behaviours and risks that caused by uncertainty, whereas SET focuses on cooperative behaviours that reduce the uncertainty and risk (Lui et al., 2009; Ke and Wei, 2008). Although TCE studies agree that trust and stable relationships are able to reduce negotiation costs and uncertainty arise from partner's opportunistic behaviour, TCE relatively lacks of explanation on the social interactions between firms that based on trust and commitment (Zheng et al., 2008). The social factors have shown to provide a more thorough explanation of trust than TCE factors (Ybarra and Turk, 2009; Ke and Wei, 2007; Lui et al., 2009), and Johansson (2008) argues that combination of TCE with SET could provide a more comprehensive explanation for inter-firms relationship.

Researchers distinguished formal contractual governance and informal relational governance (e.g. Ness and Haugland, 2005; Poppo and Zenger, 2002; Roath et al., 2002; Cavusgil and Lee, 2006; Ybarra and Turk, 2009). TCE argues the party has to apply legal contracts which specifying what is acceptable and what is not to avoid the opportunism behaviour (Williamson, 1975). Formal contractual governance refers to using of a formalised, legally binding contract or agreement to govern the inter-firm partnerships, and relational governance emphasises the role of trust, commitment, and other social capital in the governance process (Roath et al., 2002; Cavusgil and Lee, 2006). Rather than based on the regulations of contacts and agreements, relational governance is based on the social interactions in stead of exchange hazards and increases the adaptations, flexibility and information exchange (Baker et al., 2002; Gulati, 1995a, 1995b; Ring and Van de Ven, 1994; Zheng et al., 2008). In addition, relational governance reduces the dependency on contractual governance to maintain the relationship, and enhances the cooperative behaviour and alliance performance (Gulati, 1995a, 1995b; Zaheer et al., 1998; Cavusgil and Lee, 2006).

Both contractual governance and relational governance were found to enhance inter-firm relationships. For example, Lusch and Brown (1996) examined the contractual agreements and relational behaviour between manufacturers and their suppliers, and the results showed that both governances improve wholesaler business performance, such as sales, profit growth, profitability, liquidity, labour productivity, and cash flow. Claro et al. (2003) focus on relational governance, with investigation of 174 Dutch firms, and they find relational governance through joint problem solving positively affect sales growth and perceived satisfaction, whereas relational governance through joint planning only affect sales growth.

Poppo and Zenger (2002) found that the functions of two types of governances are complementary and they can enhance the partnership satisfaction. Zheng et al. (2008) support the point and argue that two governances are indeed complementary forms. However, their survey in UK *Private Finance Initiative* reveals that inter-personal relational governance is more fragile, whereas contractual governance is less degrees of freedom.

Some research found that relational governance is influential in alliance performance than contractual governance. For example, Cavusgil and Lee (2006) examined 184 business alliances and the results showed that relational governance, opposed to contractual governance, is more influential in strengthening and stabilising the inter-firm partnership, and facilitating knowledge transfer between alliance partners. Relational governance particularly could enhance alliance performance under high pressure of environmental turbulence. Moreover, their findings showed that contractual governance might impede rather than complement relational governance, because the interaction effects of two types of governances showed a negative influence on alliance performance. Lui et al. (2009) explore the governance choice in high level of asset specificity. They argue that high level of asset specificity associated hazards of opportunism and higher level of trust, and propose that both two from increases partnership performance: formal contract reduce opportunistic behaviour in high asset specificity and trust increase the cooperative behaviour. They test both governances a sample of Hong Kong trading firms, and the findings support that the predictions of social exchange theory are better than those of TCE. Lui et al. (2009) argue that relational governance is particularly important in China because the rules have not been completely established, and the formalised contracts or agreements may be less fitting in such a relation-intensive context. The studies of relationship resources, relational governance and collaboration are summarised in **Table 2.12**.

Table 2.12 Studies of Relationship Resources, Relational Governance and Collaboration

Author (s)	Topic	Sample/ Metho-dology	Variables (Independent →Dependent)	Key findings
Boardman (2008)	The affiliation with university centres and UIC	1647 university researcher, Logistic regression	Affiliation with a university biotech centre →UIC	The results demonstrate affiliation of university scientists correlate positively with informal interactions with industry, such as knowledge exchange, but not with reports of the production of economic and bibliometric outputs.
Claro, Hagelaarl & Omta (2003)	The determinants of relational governance and performance	174 Dutch suppliers of potted plant and flower products	Transaction factors, dyadic factors, environment factors→ Relational governance →Performance (growth rate, perceived satisfaction)	Using TCE, marketing channels, and business networks, this proposes that transaction factors (exchange mode, transaction-specific investments, human-specific investments), dyadic factors (length of business interaction, interpersonal trust, inter-organisational trust), environment factors (network intensity, environmental instability) are the determinants of relational governance (joint planning, joint problem solving) and performance. It is shown that relational governance is positively influenced by inter-organisational trust, information obtained from the network, and physical transaction-specific investments.

Table 2.12 Studies of Relationship Resources, Relational Governance and Collaboration *(Continued)*

Author (s)	Topic	Sample/ Methodology	Variables (Independent →Dependent)	Key findings
Houghton et al. (2009)	The influence of social capital on strategic choice	203 CEOs of rural telecommunications industry, Poisson regression	Social capital (trade associations, external personal networks, and internal personal networks) → Strategic complexity (product portfolio breadth)	This examines the effects of social capital via network on strategic complexity. It looks at three network types (i.e. trade associations, external personal networks, and internal personal networks) to assess social capital. It is shown that three network types were positively associated with strategic complexity. Moreover, it finds that larger firms and cooperative ownership associated with greater strategic complexity.
Kwon (2008)	Antecedents and consequences of international joint venture Partnerships	94 international joint ventures	Structural condition (complementarity compatibility, bond), social condition (fairness, flexibility, two-way communication) →Social capital → Performance	This uses SET to examine antecedents and consequences of international joint venture partnerships. It is shown that social capital (i.e. trust, commitment) contributes to joint venture performance (i.e. satisfaction, objectives achievement). In addition, it is shown that social capital is higher in Korean -Japanese joint ventures than Korean - Western ones, and it raises the issue of a cultural influence on the IJV partnerships.
Nakos & Brouthers (2008)	International alliance commitment and performance of SMEs	119 SMEs in Caribbean, Questionnaires, regression	Commitment →SMEs international alliance performance	This examines the antecedents of alliance commitment and find the empirical evidence of the mediating role of "process controls" on the relationship between commitment and SMEs international alliance performance.
Philbin (2008)	process model of UIC	32 interviews	NA	This highlights the social and cultural processes in collaborative research projects. It proposes a process model for university-industry research collaboration with five stages: terrain mapping, proposition, initiation, delivery; and evaluation.
Ybarra & Turk (2009)	The evolution of trust in information technology alliances	121 technology alliances during 1992–1996, Information technology industry, SEM analysis	Transaction cost factors, social exchange factors →Trust→ Change in communication/ asset specificity/ dependency, partner learning, alliance performance	This uses TCE and SET to examine the antecedents and outcomes of trust formation between alliance partners. It propose that TC factors (i.e. asset specificity, balanced asset specificity, interdependency) and SET factors (i.e. duration, communication, shared values, relationship equity) are determinants of trust. It provides evidence of trust benefit to alliance and suggests SET factors provide a more thorough explanation of trust than TCE does. Moreover, it finds that as trust increases between partners, the alliance benefits by displaying higher levels of dependency, partner learning, and alliance performance.
Zheng et al. (2008)	The dynamics of contractual and relational governance	2 UK Private Finance Initiative, Case study	NA	This explores how contractual and relational governance mechanisms are deployed in managing long-term public - private supply arrangements. It suggests that two mechanisms are indeed complementary forms but inter-personal relational mechanisms are more fragile, whereas contractual mechanisms offer less freedom.

2.7 Channels of University-Industry Collaboration

A series of studies have examined different aspects of the interaction, channels, mechanisms, knowledge transfer, and collaboration between university-industry. One group of researchers focus on the activities of specific university-industry collaborations and explore their formation and determinants. Another group of studies examine a variety of forms of university-industry collaboration, and compare their differences, such as usage and importance. Several studies have focus on the knowledge spillovers and knowledge transfers of UIC. However, this section aims to explore types of UIC interaction activities rather than discussing the findings of previous studies. Related studies are described below.

2.7.1 University-Industry Interaction Activities

Scientists must compete to build individual credibility (Bourdieu, 1974). In order to receive industrial gifts in the form of funding, reputation, and prizes, scientists may adopt gift-exchanging behaviour, such as providing free information (Hagstrom, 1966). Moreover, scientists would like to increase their personal competitive advantage by improving publications, academic ranking, and gaining a position in the competition for research grants by successfully cooperating with other parties (Bercovitz and Feldman, 2007). Interaction with others is a way to develop social capital, gain valuable resources, share knowledge, create new knowledge, and stimulate innovation (van Rijnsoever et al., 2008).

2.7.1.1 Specific channel of UIC activities

Previous studies have explored a wide range of UIC activities, and several of them have emphasised one specific activity. Spin-offs have received the most interest in exploring the determinants of university spin-off creations (e.g. O'Shea et al., 2007; Wright et al., 2006; Leitch and Harrison, 2005; Vohora et al., 2004; Nicolaou and Birley, 2003), and related studies have been reviewed in the section entitled ***2.3.3 Empirical Studies of Resources and University Spin-offs.*** University spin-offs are a third means of disseminating and converting knowledge, and new scientific discoveries, generated beyond the narrow confines of academia (O'Shea et al., 2007), are important indicators of university commercialisation activities. Research has found that factors which influence university spin-offs include university researchers' knowledge, novelty of research, personal experience, social capital, protection of intellectual property (Landry et al., 2006), industrial funding, federal funding, university faculty quality, the age and size of the university's TTO, venture capital (Powers and McDougall, 2005; O'Shea et al., 2005), intellectual property protection expenditure, and business development capabilities (Lockett and Wright, 2005).

Licensing activities is also an area of previous research. Although university licensing has been found to be unprofitable for most universities, it is growing across countries and disciplines along with patenting activities (Geuna and Nesta, 2006). Research has found that factors which influence licensing activities include university structure, university prestige (Berkowitz et al., 2001; Sine et al., 2003), university rewards for faculty involvement in technology transfer, resources allocated to the university-industry knowledge transfer process, the experience and skills of TTO members (Horng and Hsueh, 2005), and patent litigation activities (Shane and Somaya, 2007). The majority of researchers agree that TTO is important in pushing licensing activities, and Yusuf (2008) indicates that leading universities, TTO, venture capitalists, and public agencies are important intermediaries to assist knowledge transfer in licensing.

On the other hand, Perkmann and Walsh (2008) focus on academic consultancy activities, and distinguish three types of academic consultancy, namely, research-driven, commercialisation-driven and opportunity-driven. They argue that research-driven consultancy is used mainly by large and research-intensive firms for informing and validating their own R&D; commercialisation-driven consultancy is used mainly by licensee firms to accelerate technological development along a chosen path of in-sourced technology; opportunity-driven consultancy is commissioned mainly by small technology-based firms seeking to compensate for a lack of expertise or equipment. However, their studies are limited by proposition development and lack of empirical evidence and operational measures about academic consultancy. In addition, some studies emphasise informal contacts (e.g. Østergaard, 2008; Boardman, 2008), and these will be discussed in the next section.

2.7.1.2 Informal channel of UIC activities

Hagedoorn et al. (2000) indicate that a large amount of university-industry interactions might be informal. In practice, the informal contacts provide a flexible channel to share knowledge and information, and the members are more likely to acquire the latest knowledge and information through the informal contacts, it therefore facilitates knowledge transfer activities and performance. The literatures of informal interactions between university and industry are classified as three groups. The first group of studies focused on identifying the interaction forms of UIC. For example, Arvanitis et al. (2008) list 19 university-industry knowledge and technology transfer activities, and define informal contacts via phone and email, academic publications of business sector, conferences, exhibitions, and workshops are informal informational activities. They find that informal informational activities are ranked as second important activities among just followed by educational activities. Bekkers and Bodas Freitas (2008) examine the importance of 23 university-industry knowledge transfer channels in Dutch region. They find the both the industrial researchers and university researchers rank the "scientific publications in journals or books" as the most important activities, and followed by "personal informal contacts", and followed by "participation in conferences or workshops". However, the "personal contacts via alumni and professional organisations" shows less important for both industrial researchers and university researchers. In addition, they using cluster analysis and group 23 actives into 6 factor, publication, personal informal contacts, participation in conferences or workshops, and university graduates as employees are grouped into one factor. They find factor "scientific output, informal contacts and students" is more likely to be important by pharmaceutical and electrical firms than firms active in machinery and equipment activities.

The second group of studies focus on the determinants of informal contacts. For example, Boardman (2008) examines the relationships between university scientists affiliation with university biotechnology centres and their involvement with industry, and the large sample survey of 1643 US university researchers shows that the scientists affiliated with university biotech centres might use less formal interactions with industry for knowledge transfer. With the same data source, Boardman and Ponomariov (2009) explore the determinants of university researchers interacting with private companies and find that the researchers with more industrial grants, institutional affiliations, support of students are more likely to have informal contacts with industry members. Otherwise, Østergaard (2008) investigates knowledge flows between university and industry and finds that the social networks of employees are positively related informal contacts with university. Sherwood and Covin (2008) examine the knowledge acquisition in UIC and find that communications between university and industry experts increase the knowledge acquisition success in UIC, whereas formal inter-organisational collaboration teams do not show the evidence to improve knowledge acquisition success in UIC.

2.7.1.3 Multiple Channels of UIC activities

Some studies examine multiple UIC interactive activities. For example, Okamuro (2007) examines the R&D cooperation of Japanese small businesses, and finds that 44% of the respondents had collaborated with universities or public research institutes in R&D projects. The results show that technical consultation is the most popular of the various UIC forms, and this is followed by outsourcing research tasks (e.g. data analyses and tests), then by direct participation in R&D projects, and finally, utilisation of research facilities and equipment. D'Este and Patel (2007) examine the factors which influence UK university researchers' interactions with industry in five types of channel: joint research, contract research and consultancy, meetings and conferences, training, and the creation of physical facilities. They find that the individual characteristics of the academic researcher are the main factor which leads to different frequencies of usage of channel, whereas departmental characteristics and university characteristics have less impact on usage frequency. Similarly, Boardman and Ponomariov (2009) investigated why university researchers work with private companies and found that industrial funding, institutional affiliations, tenure status, support of students, scientific values, and demographic attributes all have an effect on the likelihood of US university scientists working with private companies, such as academic activities (e.g. placing students in industry jobs, and co-authoring papers), entrepreneurial activities (e.g. paid consultancy, patents, copyrights, commercialisation), and informal exchanges of knowledge (e.g. contacting people in industry to ask about research).

Chang et al. (2006) compare the performance of long-term collaborative research and short-term contract research between HEIs and industries in Taiwan, and the results confirmed that collaborative research generates more patent grants and licensing income than contract research. However, neither type of research projects has a significant impact on stimulating the creation of incubators. Inzelt (2004) identifies

18 types of university and industry interactions, and group them into four patterns according to the level of interaction, namely individuals' iinteraction (e.g. holding a lecture in the other party, regular informal discussions), individual-institutional interaction (e.g. buying university research, consultants, teaching and training, joint publications, joint supervision of theses), institutional- institutional interaction (e.g. access to equipment and facilities, contract research, joint research), and knowledge flows (e.g. research mobility and spin-off formations). He argues that governments are more able to facilitate university-industry partnerships for institutional interaction rather than individual interaction.

2.7.2 University-Industry Knowledge Transfer Activities

With the growing importance of the knowledge-based economy, scholars are more interested in knowledge transfer between universities and industry. Most researchers focus on knowledge transfer and knowledge spillover from universities to industry, and a series of studies has used a variety of methods to examine the knowledge flows from universities.

2.7.2.1 Knowledge transfer from academia to industry: codified knowledge

Earlier UIC studies view publishing and patenting as the main R&D spillover and knowledge flow activities of universities. Publication, licensing, patents, and patent citations are the most widely-used indicators to examine knowledge transfer activities from universities to industry because the codified knowledge generated by universities could access from archival data (e.g. Trajtenberg et al. 1997; Henderson et al., 1998, Mowery et al., 2001; Jaffe et al., 2000; Mansfield, 1995; Hong, 2008). University scientists with a greater citation impact on journal publications are found to have a greater number of patents (Agrawal and Henderson, 2002). Branstetter (2010) find a growing trend for industrial patents to cite academic science publications, and empirical data supports the presence of knowledge flows from universities to incubator firms in the form of backward-citations to university research.

Wright et al. (2008) identify five types of knowledge transfer activities that EU mid-range universities can contribute to industrial change, including licensing and patents, consultancy, spin-offs, contract research, and graduate and researcher mobility. They argue that these five types of activities involve the transfer of both tacit and codified knowledge, and that licensing especially largely involves codified knowledge. However, there is no empirical evidence for their study. Although a number of studies have attempted to examine the knowledge transfer from university to industry with codified indicator, little research examine the tacit knowledge flow and lacks of studies to explore the knowledge flow of joint research, contact research, consultancy, and informal contacts that are important for university-industry knowledge transfer.

2.7.2.2 Two directions of knowledge flow: outflow and inflow

While many studies have explored knowledge flows from universities to industry, Meyer-Krahmer and Schmoch (1998) argue that university-industry knowledge flows in both directions and argue that university research is not totally basic research, but also applied research. They find that academic researchers prefer collaborative research to contract research, and a possible reason for this may be the advantages of collaborative research with bi-directional knowledge flows. Rosell and Agrawal (2009) differentiate knowledge outflows and inflows and define "diffusion premium" as being *the degree to which university knowledge outflows are more widely distributed than those of firms* and "diversity premium" as being *the degree to which knowledge inflows used by universities are drawn from a more widely distributed set of prior art holders than those used by firms*. The empirical results demonstrate that university patents are more important and original than firms' patents.

Lee and Win (2004) identify two types of interaction between industry and research centres according to whether or not they share costs and facilities. They define a one-way technology flow as being "*the cost and facilities are borne by the research centre alone*" and two-way technology flow as being "the *sharing of the R&D costs and facilities between the two partners*". A one-way technology flow promotes technology flows from the research centre to the industry (or from the industry to the research centre), such as licensing, provision of technical and training services, and contract research, whereas a two-way technology flow promotes the exchange of technology and knowledge between the research centre and the industry, such as joint ventures, joint research, conferences, seminars, and industry consortia. They compare the technology transfer activities of three university research centres in

Singapore and find that "joint R&D projects" are an efficient way to generate industry commitment and increase firms' willingness to share and transfer industrial knowledge.

2.7.2.3 Knowledge transfers from academia to industry: the importance of different knowledge transfer channels

Several studies attempt to explore the most important channels when transferring knowledge from universities to industry. This group of studies is similar to that which explore the important channels for UIC activities in the previous section ***2.7.1 University-Industry Interaction Activities.*** Empirical research has not yet reached a firm conclusion on this topic. An earlier large-scale survey was conducted by Cohen et al. (1998), with a sample of 1478 R&D managers at R&D laboratories. They list 10 channels of knowledge flow from universities to industry, and the results show that publications, public meetings and conferences, informal and personal information contacts appear to be more important than other channels (e.g. patents, hires, licenses, joint ventures, contract research, consultancy, and personal exchange), and that patents are only considered to be important for pharmaceutical firms. Polt et al. (2001) analyse industry-science relationships from the perspective of cycles of innovation, and they argue that spin-offs, licensing, and joint research are important in the early stage of invention when high-level science is essential. When the invention responds to market needs, the importance of contract research, research mobility, and informal contracts is increased. Then, in the technology diffusion stage, the importance of science decreases and consultancy becomes essential.

Arvanitis et al. (2008) examine the importance of 19 university-industry activities and group five categories. With a sample of 241 university researchers in Switzerland, the results show that educational activities were given the first priority (i.e. contacts with graduates and former staff employed in the business sector, thesis projects and doctoral projects in collaboration with firms, corporate R&D projects for student and business sector scientists, joint teaching courses, teaching assignments for business, courses f institute by business sector scientists), followed closely by informal informational activities (i.e. informal contacts, conferences, exhibitions, workshops, academic publications of business sector), and followed by research activities (i.e. research projects in collaboration, longer term research contracts, research consortiums). Activities such as the utilisation of consultancy activities (i.e. expertises and reports for the business sector, consultancy for the business sector) and technical facilities activities (i.e. joint laboratories, using of technical facilities or research centres) were considered to be much less important.

Bekkers and Bodas Freitas (2008) review a series of studies and state that the codified outputs of academic research, such as publications and patents, appear to be the most critical source of knowledge for industrial innovation (Narin et al., 1997; McMillan et al., 2000; Cohen et al., 2002), while collaborative and contracted research activities seem to be a popular and important form of knowledge transfer (Kingsley et al., 1996; Meyer-Krahmer and Schmoch, 1998; Monjon and Waelbroeck, 2003). Hiring university researchers is also a useful way to transfer knowledge from universities to firms (Zucker et al., 2002; Gübeli and Doloreux, 2005), whereas informal contacts are also widely used to connect universities and industries (Meyer-Krahmer and Schmoch, 1998; Cohen et al., 2002). Bekkers and Bodas Freitas (2008) provide a comprehensive survey on this issue with a wider range of knowledge transfer channels and a wider range of sample, which consisted of university researchers and industrial researchers. They find that there was no major mismatch of the perception of importance between university researchers and industrial researchers among the 23 channels. They further cluster the 23 knowledge transfer channels into six groups with a cluster analysis, namely "scientific output, informal contacts and students", "labour mobility", "collaborative and contract research", "contacts via alumni or professional organisations", "specific organised activities", and "patents and licensing". The results show that the assessment of the importance of six types of knowledge transfer channels was different according to respondents' individual characteristics (e.g. seniority, publication record) and institutional characteristics (e.g. entrepreneurship and research environment). This shows that these characteristics impact the choice of channels to transfer knowledge from universities to firms.

Details of the findings of university-industry knowledge transfer studies are summarised in **Table 2.13. Table 2.14** illustrates the studies which examine collaborative and knowledge transfer activities between universities and industry. Lists and classifications of university-industry activities by previous studies are provided in **Appendix 5**.

2.7.3 Summary of Key Issues

Previous studies have identified several channels for interaction and knowledge transfer between universities and industry by various methods. However, some issues still need to be clarified. Firstly, UIC knowledge transfer channels overlap the context of UIC interaction channels, and most research uses these terms alternately. However, some activities are not involved with collaboration, such as reading scientific publications and other publications (e.g. Bekkers and Bodas Freitas, 2008). Secondly, it is hard to undertake a comprehensive survey of the overall university-industry knowledge transfer activities based on diverse classifications, and although researchers have attempted to explore all possible interaction activities, some are missing from the list (shown in **Table 2.14**). For example, Cohen et al. (1998) listed 10 channels, but did not survey the joint research and training activities. Boardman and Ponomariov (2009) did not investigate meetings and conferences, research mobility, joint research activities, contract research, and spin-offs. Wright et al. (2008) did not examine co-authoring, informal contacts, meetings and conferences, and joint research. Lee and Win (2004) discussed several types of one-way and two-way technology flows, but they did not mention informal personal contacts. D'Este and Patel (2007) did not explore co-authoring, informal personnel contacts, researcher mobility, and licensing activities. Arvanitis et al. (2008) missed co-authoring, research mobility, licensing and spin-off activities from their 19 university-industry interaction activities, while Bekkers and Bodas Freitas (2008) neglected to include co-authoring and spin-off activities in their 23 knowledge transfer channels.

Table 2.13 Studies of University-Industry Collaboration and Knowledge Transfer Activities

Author (s)	Topic	Sample/ Metho-dology	Variables (Independent →Dependent)	Key findings
Bekkers & Bodas Freitas (2008)	Channels of knowledge transfer, Innovation	575 industrial researchers, 454 university researchers, Dutch region	NA	This analyses knowledge transfer from the perspective of both firms and university researchers. Factor analyses investigated 23 channels with six clusters: scientific output, informal contacts and students; labour mobility; collaborative and contract research; contacts via alumni or professional organisations; specific organised activities; and patents and licensing.

Table 2.13 Studies of University-Industry Collaboration and Knowledge Transfer Activities *(Continued)*

Author (s)	Topic	Sample/ Metho-dology	Variables (Independent →Dependent)	Key findings
D'este & Patel (2007)	Factors underlying a variety of UIC interactions	1528 UK university researchers, Questionnaire survey	Individual/ departments/ universities characteristics →UIC interaction Channels	This examines the channels university researchers use to interact with industry, such as consultancy & contract research, joint research, training, patenting, and spin-off activities. It finds that the individual characteristics of researchers have a stronger impact than the characteristics of their departments or universities.
Hong (2008)	Decentralisation of knowledge transfer of Chinese universities	Patent Data, block model analysis	NA	This considers geographical constraints on knowledge transfer and the implications on China's national and regional innovation systems. It shows a decentralising / localising trend in knowledge flows from university to industry in China from 1985 to 2004.
Inzelt (2004)	Evolution of university–industry–government relationships	Hungarian business	NA	This deals with the relationship between business, universities, and government programmes. It shows that an innovation network can be created if business firms are hungry for innovation.
Lee & Win (2004)	Technology transfer of UICs	Three university research centres in Singapore, Case study	NA	This identifies the modes of technology transfer in university research centres by comparing their activities and performances in technology transfer. It suggests that a "joint R&D project" is an efficient way to increase transferability and willingness by ensuring a high level of commitment.
Polt et al. (2001)	Benchmarking UICs in Europe	NA	NA	This analyses the science source of innovation in the innovation cycle and analyses the key performance indicators of UIC interactions covering the level of the formalisation of interaction, transfer of tacit knowledge, and personal face-to-face contact.
Wright et al. (2008)	Knowledge types and the role of intermediaries of UICs	6 mid-range university, interviews and archival material.	NA	This analyses how mid-range universities contribute to industrial change through the transfer of tacit and codified knowledge in five types of UICs: spin-offs, licensing and patents, contract research, consultancy and reach-out; and graduate and researcher mobility. It summarise knowledge and technology transfer, strategies, problems, and indicators of five channels.

Table 2.14 Summary of Studies of University-Industry Collaboration and Knowledge Transfer Activities

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Chapter 3 Knowledge Transfer Mechanisms of University - Industry Collaboration

Chapter 2 reviewed literature related to interaction channels, collaboration activities, and knowledge transfer activities between universities and industry. This chapter continues to discuss ten types of university-industry knowledge transfer activities. Three types of university-industry knowledge transfer mechanisms are further developed, and these are discussed from the perspective of transaction costs, as well as from the resource-based perspectives.

3.1 University-Industry Knowledge Transfer Activities

The definition of university-industry knowledge transfer by Dosi (1982) and Arvanitis et al. (2008) is adopted, and this is as follows: *"knowledge and technology transfer between academic institutions and the business sector are understood as any activities aimed at transferring knowledge or technology, which may help either the company or the academic institute, to further pursue its activities."* Based on the literature review, ten key university-industry knowledge transfer activities are identified, which appear to be relatively more important in empirical UIC studies which survey the importance of UIC channels.

3.1.1 Spin-offs

University and academic institutions play an important role in initiating spin-off activities because of their excellent ability to generate new scientific and technological knowledge, especially at the invention stage (Polt et al., 2001). When members of spin-off companies and universities are able to access their partner's existing facilities and expertise under a formal agreement, their pattern of knowledge transfer activities are horizontal, complex, and involve a two-way technology flow (Lee and Win, 2004; Inzelt, 2004). Spin-off companies can then be generated in different forms according to the founder:

(i) University Spin-off or Academic Spin-off: This is established by the department or university. It develops its knowledge and makes a profit by selling its R&D results and intellectual property through formal agreements. For example, the Feng-Chia University established the Umbrella Technology Co., Ltd. When universities cannot estimate the value of their technology through a licensing arrangement, they tend to create spin-off companies (Franklin et al., 2001).

(ii) Corporate Spin-off or Firm Spin-off: This is created within a parent company to create a new company with the university involved in knowledge transfer activities within the company (Wright et al., 2008). For example, Huayang Co., Ltd established a new joint venture company with National Cheng-Kung University.

(iii) Independent Spin-off, Incubator, or Start-up: This is launched by individuals, such as university researchers, graduates, or business entrepreneurs. The university is involved in knowledge transfer activities with the company's founders. This is more common in high-tech industries (Lee and Win, 2004), and because there is no direct financial relationship between the university and the incubator, the university has little incentive to collect data about this type of start-up company and its impact (Wright et al., 2008).

3.1.2 Licensing

Licensing refers to a formal agreement for the exchange of patents, know-how or other intangible resources for a fee, royalty, or other form of payment. Licensing has been identified as a popular way of university technology transfer (Siegel et al., 2003b). Siegel et al. (2003b) indicate that licensing activities engage universities, TTO, and firms. They begin with a discovery by a university scientist, and the TTO evaluates the potential for commercialisation and decides whether or not to patent the innovation. Once the patent has been awarded, the TTO can market the technology and work with private firms to negotiate a licensing agreement for the intellectual property (shown in **Figure. 3.1**).

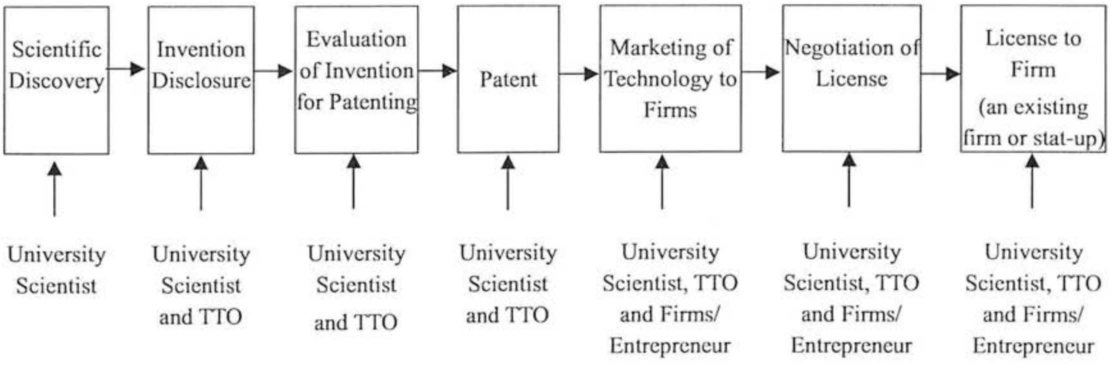

Figure 3.1 How Technology Is Transferred From Universities To Firms

Source: Siegel et al. (2003b)

Licensing is one way knowledge flows from universities with the transfer of explicit knowledge (Lee and Win, 2004). When the research invention has a commercial potential, universities may need to decide between setting a spin-off and licensing it to another institution (Wright et al., 2008). The top universities usually prefer spin-offs, but second-rank universities are more likely to use licensing (Di Gregorio and Shane, 2003). Compared to spin-offs, knowledge transfer through licensing and patenting involves awarding less-than-ownership rights of intellectual property to a third party, to allow the third party to utilise the intellectual property (Wright et al., 2008; Polt et al., 2001), and licensing is more likely to occur if a university already has experience of licensing (Shane, 2004, Wright et al., 2008). Bekkers and Bodas Freitas (2008) found that industrial R&D managers consider licensing to be more important than spin-offs in knowledge transfer, whereas university R&D researchers consider spin-offs to be more important than licensing.

3.1.3 Joint Research

Instead of an equity arrangement, the university and industry may choose a formal arrangement, such as a joint research or contract research agreement to share knowledge and technology. Joint research is research undertaken by both university and industry with a formal contract (D'Este and Patel, 2007). Joint Research refers to a situation where the partners share the R&D work, and each of them contributes funds, personnel, services, facilities, equipment, and other resources, to conduct specific research (Okamuro, 2007). Joint research and contract research are said to be the most important form of knowledge transfer (Meyer-Krahmer and Schmoch, 1998; Monjon and Waelbroeck, 2003), and joint research is given more priority than contract research in terms of knowledge transfer for both industrial scientists and universities (Bekkers and Bodas Freitas, 2008).

3.1.4 Contract Research

Contract Research refers to research commissioned by industry and undertaken only by a particular university (D'Este and Patel, 2007). Contract research is usually launched with the provision of industrial funds, and the university provides the knowledge in a collaboration ranging from a few months to years (Rothwell et al., 1989). University-industry contract research usually involves applied research, which is still in the early stage of invention, and only a portion of the knowledge is actually codified at this early innovation stage (Poyago-Theotoky et al., 2002; Wright et al., 2008). Through contract research, industry can access the knowledge of university scientists and utilise the unique capability of the university to work for commercial benefit (Lee and Win, 2004).

3.1.5 Consultancy

Consultancy typically refers to a situation where the university provides advice, information or technical services to find the solution to a problem, or provide greater insight into knowledge, and it is usually a short-term formal contract (Denis and Lomas, 2003; Lee and Win, 2004; Wright et al., 2008). Perkmann and Walsh (2008) distinguished three types of academic consultancy for firms, namely research-driven consultancy, commercially-driven consultancy, and opportunity-driven consultancy. They proposed that these three forms of academic consultancy have different impacts on universities and firms, and their propositions are summarised in **Table 3.1**. They argued that only research-driven consultancy has a positive impact on academics' research productivity, while commercially-driven and opportunity-driven consultancy has a lesser influence or negative impact on research productivity. Although consultancy is a common way to transfer knowledge from universities to industry, it seems to be less important in terms of knowledge flows from universities (Arvanitis et al., 2008; Bekkers and Bodas Freitas 2008).

Table 3.1 Characteristics and Impact of Academic Consultancy

	Opportunity – driven	Research – driven	Commercially – driven
Characteristics			
Motive	Income	Research opportunities	Technology development
Relationship	Short-term	Long-term	Project-bound
Type of knowledge	Openly accessible, specialist expertise	embedded strategic judgment, know-what	Tacit expertise
Impacts			
Shift away from basic research	No	No	No
Impact on academic productivity	-	O	+
Contribution	Problem-solving, hires expert labour	Enabling and accelerating development	'Windows' on new technologies, strategic advice
Benefiting firms	Small technology-based firms	Licensees (up-start technology companies and existing companies)	Large, science and technology-intensiv e firms

Source: Perkmann and Walsh (2008)

3.1.6 Training and Education

There is no consistent definition of university-industry training and educational activities. For example, Bekkers and Bodas Freitas (2008) highlight practical student training activities, such as students working as trainees or employees. Boardman and Ponomariov (2009) focus on the assistance of university research to place students a job in industry. D'Este and Patel (2007) state that educational training includes student training and employee training, and they focus on the joint supervision of PhD students' training and the course enrolment or personnel exchanges of employee training. Arvanitis et al. (2008) indicate that university-industry education involves a wide range of activities, including student participation in R&D projects, programmes by business sector scientists, teaching assignments for business sector staff, and contacts with graduates/former staff who are employed in the business sector. Under this different educational scope, there is no consistent conclusion of the importance of education and training activities in UIC knowledge transfer. Arvanitis et al. (2008) found that educational and training activities are the most important university-industry knowledge transfer channels for university researchers. In contrast, Bekkers and Bodas Freitas (2008) found that both industrial R&D researchers and university researchers consider that "education and training delivered by universities" to be much less important in university-industry knowledge transfer.

3.1.7 Research Mobility

A transfer of personnel may facilitate the exchange of expertise and information, either from university to industry or from industry to university (Lee and Win, 2004). Most studies examine the mobility of university graduates and university researchers (e.g. Argote et al., 2000; Wright et al., 2008; Jaffe et al., 1993). Bekkers and Bodas Freitas (2008) highlighted researcher mobility, and found that this is particularly important where there is a lack of explicit knowledge for technology breakthroughs. They also found that younger industrial and university researchers or university researchers working with psychology and cognitive studies are more likely to perceive 'research mobility' to be an important channel of knowledge transfer. This thesis follows Bekkers and Bodas Freitas (2008) and focuses on research mobility.

3.1.8 Informal Personal Contact

Informal personal contact refers to personal connections outside formal official contracts, and informal contacts between universities and firms have recently received increasing attention. Formal agreements only represent part of university-industry interactions, and a large proportion of them may be informal (Hagedoorn et al., 2000). Arvanitis et al. (2008) maintain that Swiss university researchers rank informal personal contacts as the most important university-industry knowledge-transfer channel. Similarly, Bekkers and Bodas Freitas (2008) found that both industrial researchers and university researchers ranked scientific publications as being the most important knowledge transfer channel, but this was closely followed by personal informal contacts. Sherwood and Covin (2008) found that informal communication via e-mail, telephone, and visits between technological experts can facilitate the transfer of both tacit and explicit knowledge. Azagra-Caro et al. (2006) suggest that formal and informal relationships are not interchangeable, and informal relationships usually precede or initiate formal projects.

3.1.9 Meetings and Conferences

Meetings and Conferences refers to group connections which do not involve formal contracts to exchange knowledge and information. Meetings and conferences are informal interactions, whereas contract activities are formal agreements (D'Este and Patel, 2007). Meetings and conferences were found to be a widespread form for university researchers to interact with industry, and this is supported across all scientific disciplines (D'Este and Patel, 2007). Through informal group contacts, members of industries and universities present and exchange their ideas, practices and research results, and this facilitates knowledge sharing, knowledge creation, and relationships between universities and firms.

3.1.10 Co-Authoring

Publication appears to be an important input to industrial innovation for access to knowledge which is developed by a university (McMillan et al., 2000; Cohen et al. 2002; Bekkers and Bodas Freitas, 2008). Academic publications, such as journal papers and books are found to be the most important source to access to university knowledge (Bekkers and Bodas Freitas, 2008). Although reading and citing publications developed by universities is common, this thesis highlights the co-authored papers between universities and industries, because the former is not necessarily engaged in collaboration or relationships. In a process of joint-publication, industrial and university researchers can interact more to share knowledge, and this is a useful way to transfer tacit knowledge into explicit knowledge.

Based on studies of the perspective of innovation cycles and essential science (Polt et al., 2001), unilateral versus bilateral knowledge flow (Lee and Win, 2004), tacit versus explicit essential knowledge (Wright et al., 2008), the interactions formed with individuals or institutions, the complex levels of cooperation, and the role of government (Inzelt, 2004), and the motivational drive of academic consultancy for industry (Perkmann and Walsh, 2008), this thesis arranges the features of ten types of university-industry knowledge transfer activities. The knowledge transfer features of 10 types of university-industry knowledge transfer activities are summarised in **Table 3.2.** and illustrated in **Figure 3.2.** Spin-offs, joint research, licensing, and co-authoring usually provide new technical knowledge which is mainly needed in innovation activities. The former two usually take place among institutions with a higher level of alliance complexity, and governments may engage in these activities with a triple helix government-industry-academy cooperation. Licensing takes place mainly among institutions with one-way explicit knowledge transfer, and co-authoring usually arises with a two-way transfer of high science essential knowledge in a low level of alliance complexity. In the later stages of innovation activities, when the invention has application potential, knowledge transfer is more likely to occur via informal contacts, research mobility, and contract research to seek information of market developments and conduct the projects with less innovation. These activities normally involve a medium level of essential science and the transfer of more tacit knowledge. When technology development is in the last stage of the innovation cycle, i.e. product and process differentiation, meetings and conferences, consultancy and training are performed by institutions to learn from good practice and to diffuse knowlegdge, and these activities usually involve explicit knowledge transfer and the former two usually engage in a one-way knowledge transfer with a lower degree of essential science.

Table 3.2 University-Industry Knowledge Transfer Acitivities

	Innovation cycle	Science essential	Motivation Driven	Know-ledge flow	Know-ledge essential	Interaction Level	Government involvement	Cooperation Level
Spin-off	(1)	High	Commercialisation	Two way	Tacit	Institutional	Horizontal triple helices	Complex Cooperation
Licensing	(1)	High	Opportunity	One way	Explicit	Institutional/ (Individual)	Isolated/ Arm's length	Cooperation
Joint Research	(1)&(2)	High	Commercialisation/ Research	Two way	Tacit	Institutional	Horizontal triple helices	Complex Cooperation
Contract Research	(2)	Medium	Commercialisation /Research	One way	Tacit	Institutional	Horizontal triple helices	Cooperation
Consultancy	(3)	Medium	Opportunity	One way	Explicit /Tacit	Institutional/ (Individual)	Vertical, far distance	Cooperation / Interaction
Informal contacts	(2)	Medium /Low	Opportunity /Commercialisation/ Research	Two way	Tacit	Individual	Isolated	Interaction
Meetings and conferences	(2)	Medium	Research	Two way	Explicit /Tacit	Individual	Isolated	Interaction
Education/ Training	(3)	Low	Research	One way	Explicit /Tacit	Institutional	Vertical, far distance	Cooperation / Interaction
Graduate Mobility	(3)	Low	Research	One way	Tacit	Institutional/ (Individual)	Horizontal triple helices	Cooperation / Interaction
Researcher Mobility	(2)	Medium	Commercialisation/ Research	One way	Tacit	Institutional/ (Individual)	Horizontal triple helices	Cooperation / Interaction
Co-authoring	(1)	High	Research	Two way	Explicit /Tacit	Institutional/ (Individual)	Vertical, far distance	Cooperation

(1)= Invention; (2) = Adaptation to Market Needs; (3) = Diffusion of Technology; Science essential= Relevance of Science as an essential source of innovation

Source: The Author

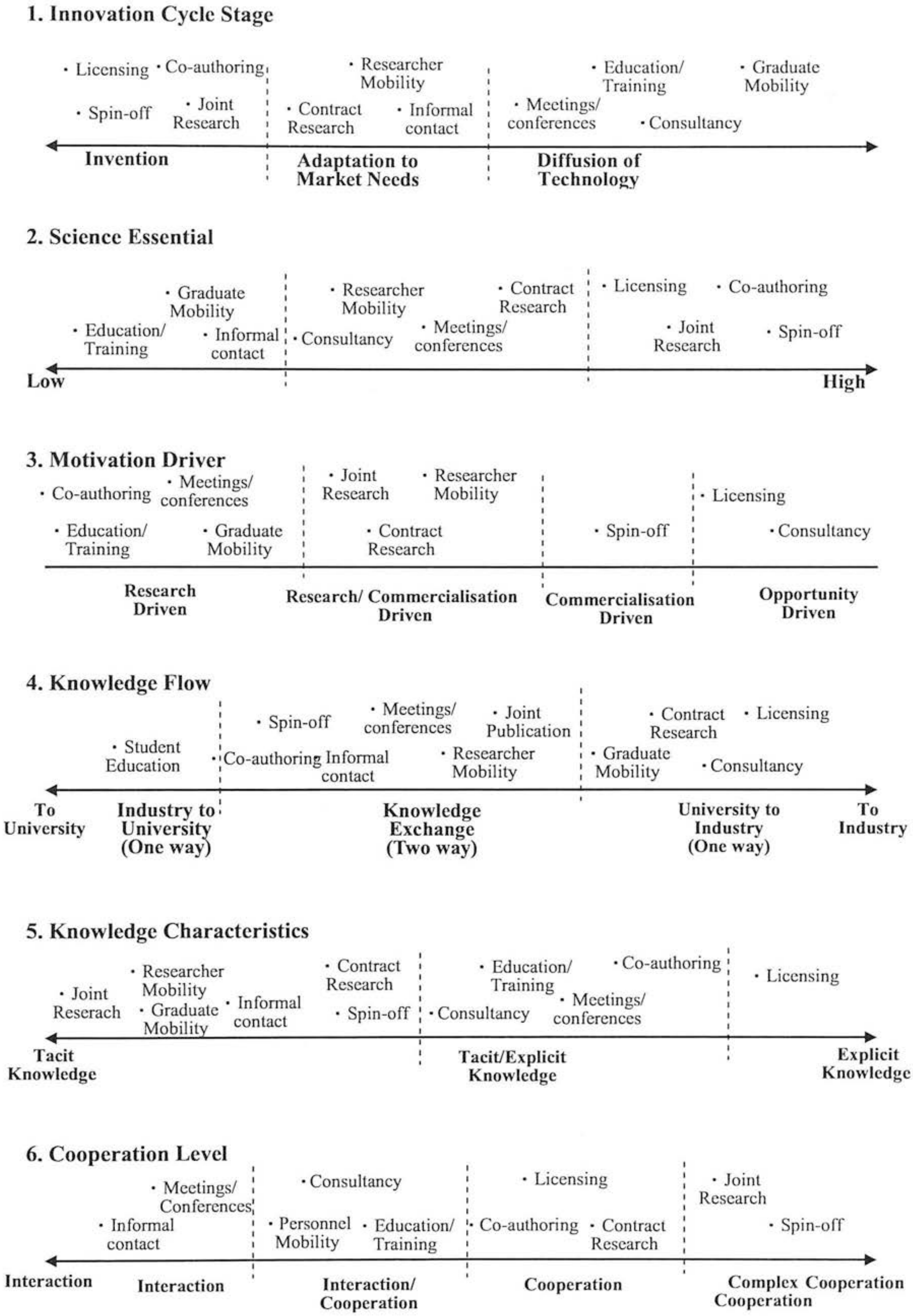

Figure 3.2 Features of University-Industry Knowledge Transfer Activities

A series of studies has examined the determinants and importance of various university-industry collaborations and interaction activities. However, very few of these have been able to explore knowledge transfer mechanisms with theoretical paradigms. In order to provide a theoretical explanation of university-industry knowledge transfer, this thesis employs TCE and RET to develop university-industry knowledge transfer mechanism.

3.2 Transaction Cost Economics and Technology Alliance Governance

The TCE assumes that the choice of internalisation or external cooperation is dependent on the transaction costs (Williamson, 1985). Williamson (1991) identifies three types of governance, namely, market governance, hierarchical governance, and hybrid governance. Market governance refers to activities conducted outside the firm with a market exchange which is performed through the legal system. Hierarchical governance refers to activities which are performed within the organisation, such as vertically integration. Hybrid governance is a compromise between hierarchical and market governance, and it ranges from formal mechanisms, such as equity arrangements and contractual agreements, to more informal mechanisms, such as information-sharing and joint planning (Rindfleisch and Heide, 1997; Chen, 2002). An inter-firm alliance is hybrid governance, and it can be divided into two primary categories, namely, market-dominated and hierarchy-dominated forms (Osborn and Baughn, 1990; Gulati, 1995a, 1995b).

These governance modes can be ranked in a continuum from hierarchy to market. For example, Gulati and Singh (1998) ranked joint ventures at the hierarchical end, followed by minority holdings and strategic alliances in a market transaction at the market end. Based on TCE and RBV, Das and Teng (2002) ranked these governance codes according to their degree of integration as equity joint ventures, minority equity alliances, bilateral contract-based alliances, and unilateral contract-based alliances. Also based on TCE and RBV, Chen and Chen (2003) distinguished two types of resource-sharing schemes in contractual alliances, namely, integration alliance and exchange alliance. Integration alliance refers to the activities and resources which are integrated within a certain organisation, but serve the partners, such as joint R&D agreements. Exchange alliance refers to situations when resources which are first exchanged and then utilised independently by each partner, such as out-sourcing activities. An Integration alliance exhibits more control, and are more structured than exchange alliances. Otherwise, Santoro and McGill (2005) ranked equity joint ventures at the hierarchy end, followed by minority equity alliances, bilateral alliances, and licensing at the market end. Kasch and Dowling (2008) examined commercial strategies and ranked equity-based cooperation as being full integration at the integrated end (rights are retailed), followed by bilateral cooperation, and unilateral cooperation at the less integrated end (rights are released).

Chen (2002) argues that technological alliances are formed to minimise the cost of uncertainty and acquiring and securing critical resources for a firm's competitive advantage. She identifies two primary technological alliances, namely, equity-based and contract-based. Equity-based alliances include joint ventures and equity acquisitions, while contract-based alliances refer to joint R&D development, strategic agreements, and licensing agreements. In the same vein, van de Vrande et al. (2009) ranked technology outsourcing according to the degree of integration. M&As are the most integrated, followed respectively by joint ventures, minority holdings and corporate venture capital investments, while non-equity alliances as the least integrated. Silipo (2008) examined contractual R&D cooperation agreements according to the level of sharing information and costs, and ranked research joint ventures (fully sharing information and costs) as being the strongest form, followed by cross-licensing agreements (R&D coordination plus information sharing), while the coordination of R&D activity as the weakest form. The governance studies within the continuum model are summarised in **Table 3.3**.

Table 3.3 Governance Modes with a Continuum Perspective

Author	Governance						
Arranz & de Arroyabe (2007)		Structural			Safeguard		
Chen (2002)		Licensing	Joint Development, Strategic Agreement		Minority Equity Alliances	Joint Ventures	Mergers/ Acquisitions
Chen & Chen (2003)		Exchange Alliance (e.g. Out sourcing)	Integration Alliance (e.g. Joint R&D agreement)			Joint Ventures	
Das & Teng (2002)		Unilateral Contract-Based Alliances	Bilateral Contract-Based Alliances		Minority Equity Alliances	Equity Joint Ventures	
Gulati & Singh (1998)			Strategic Alliances		Minority Holdings	Joint Ventures	
Kasch & Dowling (2008)		Unilateral cooperation (e.g. licensing)				Bilateral Cooperation with Exchanged Equity	Full Integration
Osborn & Baughn (1990)	Market		Market-Dominated Hybrid		Hierarchy-Dominated Hybrid		Hierarchy
Williamson (1991)	Market		Hybrid				Hierarchy
Santoro & McGill (2005)		Licensing Cross-Licensing	Bilateral alliances		Minority Equity Alliances	Equity Joint Ventures	
Silipo (2008)	Coordination of R&D activity	Cross-Licensing agreement				Research Joint Venture	
van de Vrande et al. (2009)			Non-Equity Technology Alliances	Corporate Venture Capital	Minority Holdings	Joint Ventures	M&As/ Integrated Technology Sourcing

Source: The Author

According to **Table 3.3**, inter-firm R&D alliance governance modes can be ranked with a continuum line according to their degree of integration. M&As are the most integrated, followed respectively by joint ventures, minority holdings, joint Research, contract research, licensing, and consultancy. Dichotomously, they can be grouped as equity-based and non-equity-based alliances. Equity-based alliances have a greater level of hierarchy and interaction, such as M&As, joint ventures, and a minority of equity alliances. Otherwise, non-equity alliances refer to market hybrid governance, such as joint research, contract research, licensing, and consultancy. Joint research involves bilateral contact-based cooperation, while licensing and consultancy involve unilateral contact-based cooperation. Contract research may involve bilateral or unilateral cooperation, depending on whether the partners share facilities and knowledge. The governance modes of R&D collaboration are illustrated in **Figure 3.3**.

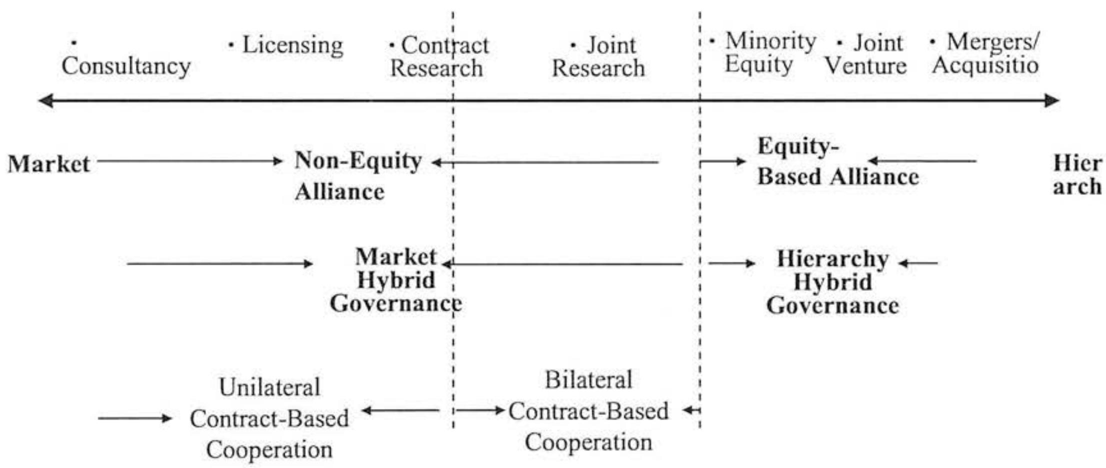

Figure 3.3 Governance Modes of R&D Collaboration

Source: The Author

3.3 University-Industry Knowledge Transfer Mechanism

Although a great many studies have examined the determinants of UIC R&D activities or the importance of UIC knowledge transfer activities, few of them have explored the knowledge transfer mechanisms of an R&D collaboration. Knowledge transfer mechanisms can be considered to be governances by which firms or universities choose to minimise the costs associated with the transfer of knowledge, including acquiring university knowledge or knowledge exchange. Several inter-firm R&D collaboration activities are similar university-industry R&D collaboration activities, such as joint research, contract research, licensing, and consultancy. However, university–industry collaborative mechanisms are different from governance mechanisms in the inter-firm context. Firstly, inter-firm equity-based alliances such as mergers and acquisitions lie beyond the scope of UIC, because the university seldom sells/merges or is sold/merged with another business institution. Otherwise, non-equity alliances such as joint research, licensing, contract research and consultancy, are more popular under UIC conditions. Secondly, compared with R&D alliances with peer industries in terms of competitors, suppliers and consumers, an R&D alliance with a university has the advantage of producing less risk of creating competitors. In addition, contract research, training, and consultancy activities may occur with other firms, but they are seldom discussed in inter-firm alliance studies. Thirdly, several university–industry collaborative activities, such as researcher mobility, co-authoring papers, and conferences, are more likely to be undertaken with universities, and firms do not always conduct these activities with other firms. In addition, although a TCE provides an economic perspective to determine the governances by analysing the transaction costs, a university-industry collaboration may exist, even if it is not cost-efficient. Therefore, a RET is employed in this thesis to explore informal relation-based mechanism and three types of knowledge transfer mechanism are identified below.

3.3.1 Equity-Based Mechanism

An alliance governance is determined by the magnitude of the transaction costs involved, since the greater the transaction costs, the more hierarchical a level of alliance will be chosen (Pisano, 1989). TCE is not only concerned with alliance structures and organisation structures, but it can also be applied to explore the transaction costs of the exchange activities (Chen and Chen, 2003). In terms of knowledge exchange activities, equity-based alliances are a more efficient method to transfer tacit knowledge within organised embedded governance than contract-based alliances (Kogut, 1989). When knowledge is less able to be codified and harder to teach, it is more likely to be transferred through wholly-owned operations (Kogut and Zander, 1996). Spin-offs exhibit specific university-industry collaboration activities which involve equity arrangements. Compared to other knowledge transfer activities, spin-offs are the most hierarchical mechanism to control knowledge transfer and exchange between universities and industry. When a joint venture between a university and firm produces a spin-off company, equity sharing provides a safeguard mechanism to reduce opportunistic behaviour and build up high exit costs, so that the two parties can work together by sharing costs and profits with a formal binding (Pangarkar, 2003; Chen and Lin, 2004), and the best brains can also be brought together to resolve any problems (Lee and Win, 2004). Moreover, this provides a balance between long-term and high-risk research and short-term work, which can promptly be commercialised (Lee and Win 2004).

3.3.2 Contract-Based Mechanism

Contract-based governance stresses the use of formalised, legally-binding agreements and contracts to resolve the opportunistic problem, govern the partnership, and stabilise the relationship (Macneil, 1978; Cavusgil and Lee, 2006). Both equity-based and contract-based governance rely on legally-binding agreements and contracts. The difference is that equity-based governance is involved with an equity arrangement. The arms length of contract-based governance is likely to occur when the technology is more explicit and discrete (Teece, 1998), because the codified knowledge can be more efficiently transferred through the market or contractual agreements (Arora and Gambardella, 1994; Chen and Lin, 2004).

Several university-industry cooperative arrangements are based on formal contract agreements instead of equity exchange, for example, joint research, contract research, researcher mobility, training, licensing, and consultancy. Different from contract agreements in inter-firm cooperation, which range from licensing or agreements of R&D/technology, marketing, distribution, manufacturing, and production (Chen and Lin, 2004), university-industry cooperative contract agreements usually focus on R&D activities.

On the continuum line of governance modes, these contract-based governances are market hybrid governance modes. Licensing and consultancy are more market mechanisms, and are less integrated because they can simply be bought from the market. In addition, from the knowledge flow perspective, joint research and research mobility are engaged in a bilateral contract-based cooperation with a two-way knowledge exchange, whereas licensing, consultancy and training are related to unilateral contract-based cooperation with one-way knowledge transfer. Contract research lies between two types of knowledge flow, because the business sector may or may not share its knowledge and facilities in research programmes. The university-industry knowledge transfer activities and university-industry knowledge transfer mechanisms are illustrated in **Figure 3.4.**

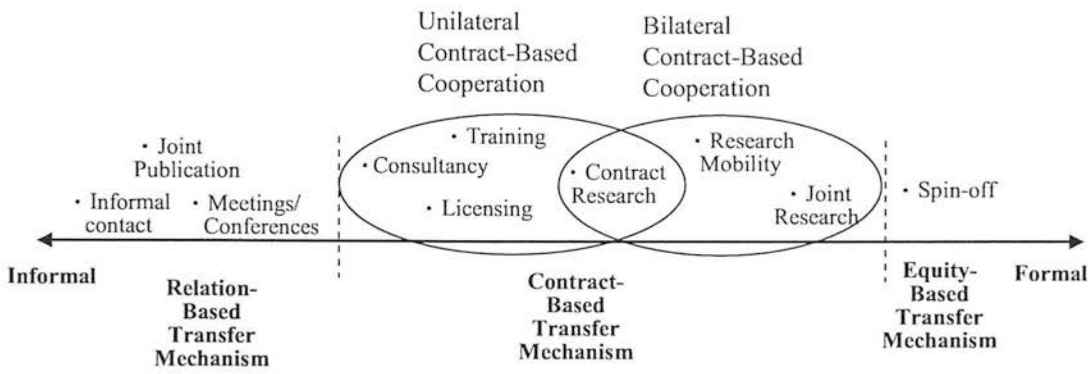

Figure 3.4 University-Industry Knowledge Transfer Activities and Mechanisms

Source: The Author

3.3.3 Relation-Based Mechanism

Informal contact has been identified as being one of the forms of interaction between universities and industry (e.g. Cohen et al., 1998; Polt et al. 2001; Boardman, 2008; Østergaard, 2008), and empirical evidence shows that informal information contacts are more important than formal ones (e.g. Arvanitis et al., 2008; Bekkers and Bodas Freitas, 2008; Sherwood and Covin 2008). While equity-based governance and contractual-based governance uses equity, formalised and legally-binding contract agreements to govern the partnership, Cavusgil and Lee (2006) suggest that relation-based governance is essential to coordinate mechanisms to determine the quality and performance of collaboration. Relation-based mechanism emphasises the use of an informal binding to facilitate the partnership. Empirical results demonstrate that both contract-based and relation-based governance have a positive effect on inter-firm relationships (Lusch and Brown, 1996; Poppo and Zenger, 2002), and relation-based governance performs better in some cases (Cavusgil and Lee, 2006) because it provide a flexible interface to exchange information and knowledge (Zheng et al., 2008). Few studies have explored the relation-based governance of university–industry collaborations and knowledge transfer activities. This thesis defines interaction without formal contracts or equity exchange as being considered to be relation-based transfer mechanism, such as informal contacts, meetings and conferences and joint publications.

Chapter 4 Research Model and Hypotheses

4.1 Research Model

The aim of this study is to investigate how firms enhance their knowledge through knowledge transfer activities with their academic partners. It focuses on the nature of resources and transaction costs as determinants of university–industry knowledge transfer activities and knowledge transfer performance. The thesis highlights firms' innovative performance in transferring knowledge, including knowledge acquisition, knowledge creation, and commercial success.

The recource-basad theory, transaction cost economics and social exchange theory, is employed to understand the mechanisms, determinants, and consequences of university–industry knowledge transfer. Three types of mechanisms are developed to explain the knowledge transfer between universities and industries, including equity-based transfer, contract-based transfer and relation-based transfer. The research model includes three influencing categories, namely, resource factors, dependency and complementarity factors, and transaction cost factors. Based on empirical literature and the RBT, five types of resources are proposed to influence knowledge transfer activities and knowledge transfer performance, namely, property-based resources, knowledge resources, organisational resources, relationship resources, and university TTO resources. Apart from TTO resources, this study identifies two sets of resources according to different contributors, i.e. university and industry, respectively. It is proposed that both sources of resources will influence university–industry knowledge transfer and the knowledge transfer performance.

Moreover, it is posited that resource dependency and resource complementarity caused by the asymmetric contribution of the university and industry will also affect university–industry knowledge transfer and the knowledge transfer performance. In addition, according to TCE, it is proposed that uncertainty and asset specificity may affect the choice of knowledge transfer mechanisms with academic partners. The research model is presented in **Figure 4.1**.

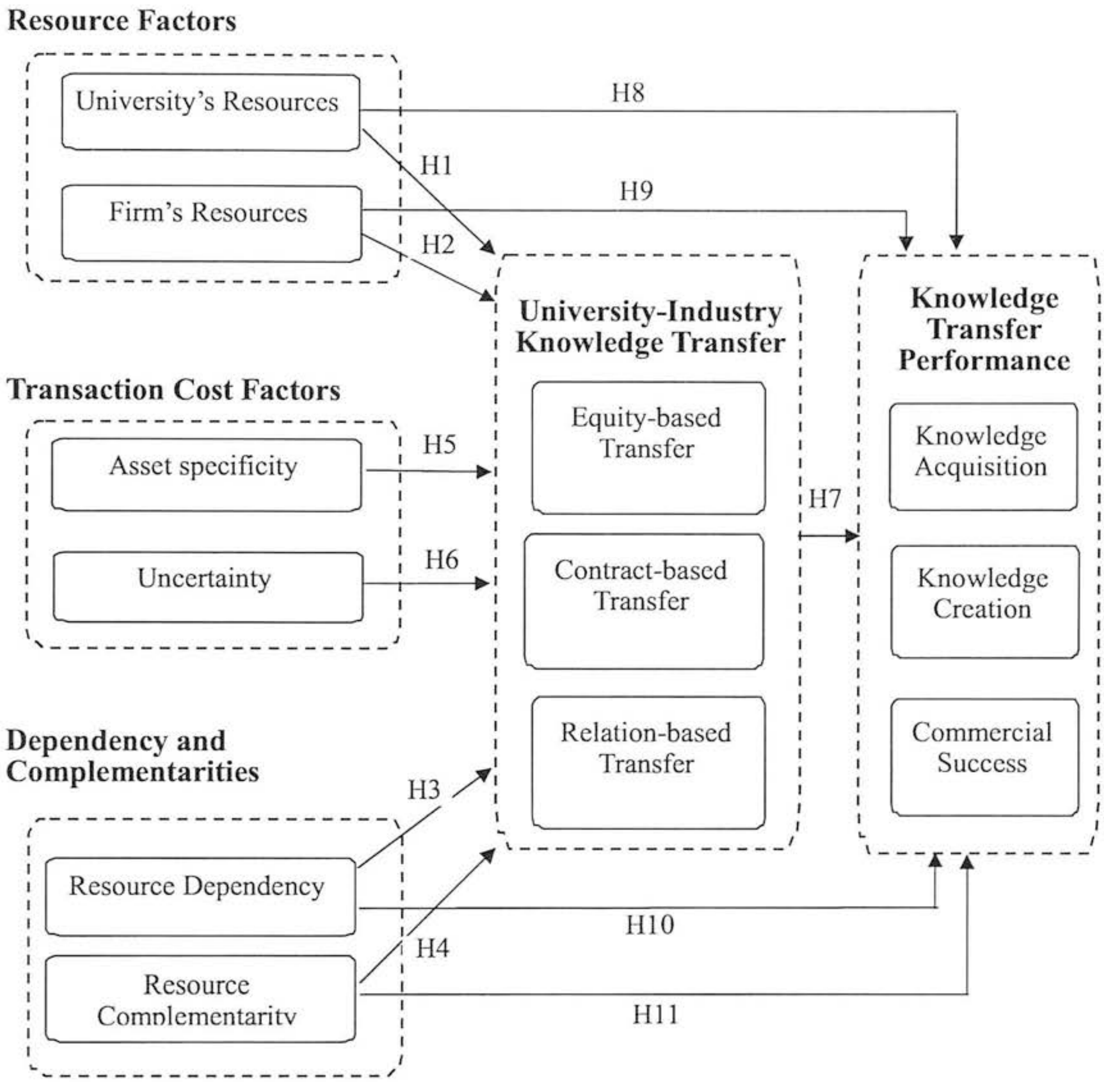

Figure 4.1. Research Model of University-Industry Knowledge Transfer

4.2. Research Hypotheses

The relationship between resource factors, resource dependency, complementarity, transaction cost factors, university-industry knowledge transfer, and knowledge transfer performance is discussed below.

4.2.1 Resources and Knowledge Transfer

RBT emphasises firms' available strategic resources, and views a firm as a unique bundle of assets and resources (Wernerfelt, 1984; Dierickx and Cool, 1989). Because their resources are finite, all organisations must engage with others to obtain those they require (Dyer and Singh, 1998; Chen, 2002). If a firm lacks the necessary resources internally to perform certain activities, it will seek to outsource them from external providers through alliance opportunities to exploit partners' resources (Kasch and Dowling, 2008; Gulbrandsen et al., 2009). When firms need resources which cannot be purchased via the market, collaborations and alliances are particularly important for them to acquire the resources from the outside world. By gaining partners' resources through exchange and co-development by linking with others, firms can exploit the opportunities and neutralise the threats of the external environment to maximise the value of their own resources (Barney, 1991).

From the resource perspective, the formation of an alliance maximises the value of a firm by pooling resources, and the motivation for forming an alliance is gaining access to the ally's resources (Yasuda, 2008). Therefore, firms would much rather collaborate with universities which have greater resources. On the other hand, universities also tend more to collaborate with industrial partners which own more resources, as well as organisations with more resources and a greater ability to span boundaries to form an alliance and perform knowledge transfer activities. Therefore, relationships are hypothesised as follows:

H1. Universities' resources are positively related to university-industry knowledge transfer, including equity-based, contract-based, and relation-based transfer.

H2. Firms' resources are positively related to university-industry knowledge transfer, including equity-based, contract-based, and relation-based transfer.

4.2.1.1 Property-Based Resources and Knowledge Transfer

With increasing competition to gain access to a reduced pool of public funds (Powers and McDougall, 2005), universities are forced to seek industrial funding to conduct their research programmes. Industrial R&D investment in universities enables firms to conduct research which they would normally be ill equipped to do, and to gain access to talented researchers and students (Rossner et al., 1998; Bozeman, 2000; Powers McDougall, 2005). High-tech firms in particular rely on universities for conducting basic scientific research programmes facilitated by industry grants (McMillan et al., 2000; Powers McDougall, 2005). Bogler (1994) found that industry grants improve the favourable attitude of university scientists toward university-industry collaboration. Industry property-based resources were also found to increase university researchers' willingness to become involved with industry in formal agreements to transfer knowledge. For example, the number or amount of industry grants were found to facilitate university-industry contract research and joint research (Bozeman and Gaughan, 2007), licensing activities (Yusuf, 2008), and university researchers working as consultants in private companies (Bozeman et al., 2001, Powers and McDougall, 2005; Boardman, 2008). Since university researchers need more funding to conduct more research and promote R&D development, the provision of industry funding and R&D facilities increase their willingness to receive financial compensation in exchange for their findings (Yusuf, 2008).

In addition, when a firm has more grants, university researchers are more likely to actively connect to industry via personal contacts or conferences for the chance to collaborate, and this increases informal relation-based university-industry knowledge transfer activities. Compared to university funding, industry grants are more focused on commercial activities, and this is found to be critical for university researchers to develop entrepreneurial activities (Van Looy et al., 2004). Industry grants have the advantage of commercial orientation, applied research orientation, and the ability to utilise human capital to generate more commercially-feasible technologies, and to generate targeted outcome (Powers and McDougall, 2005; Yusuf, 2008). Industry property-based resources provide universities with the necessary resources and commercial expertise to successfully transfer technologies to the marketplace, and this has been found to facilitate the creation of university spin-offs, especially for companies which are resource-deficient (Wright et al., 2004; Carayannis et al., 1998; Di Gregorio and Shane, 2003; Powers and McDougall, 2005; Landry et al., 2006; De Coster and Butler, 2005; Leitch and Harrison, 2005). Therefore, it is hypothesised that:

H2-1. Firms' property-based resources are positively related to university-industry knowledge transfer, including equity-based, contract-based, and relation-based transfer.

On the other hand, university property-based resources also provide the motivation for a firm to connect with a university. Bagchi-Sen (2007) investigated the strategic considerations of a U. S. biotechnology firm to collaborate with a university, and found that 25% of the respondents stated that they might link with a university "to access federal funds". Collaboration with universities and research centres enable firms to secure financing to undertake research projects under their auspices (Bayona Sáez et al., 2002). Because of their resource constraints SMEs are particularly willing to collaborate with universities to access public R&D funding and facilities (McAdam et al., 2006). When entrepreneurs lack sufficient budget to conduct research projects, they can actively connect with a university to exploit the university's resources via formal projects, such as contract research, joint research, licensing, consultancy and training, or informal contacts, such as attending conferences or personnel contacts. In addition, O'Shea et al. (2005) and Landry et al. (2006) found that universities with a larger research budget are more likely to create spin-off companies. These universities' property-based resources increase their ability to generate more technological inventions with commercial potential, and this facilitates university spin-offs. On this basis, the following research hypothesis is proposed:

H1-1. Universities' property-based resources are positively related to university-industry knowledge transfer, including equity-based, contract-based, and relation-based transfer.

4.2.1.2 Knowledge Resources and Knowledge Transfer

Universities are usually considered as technological sources, and firms as technological recipients (Østergaard, 2008). A critical reason for firms to link with universities is to obtain the knowledge generated by the universities, which enables the firms to make important innovative breakthroughs (Powers and McDougall, 2005; Bayona Sáez et al., 2002; Bercovitz and Feldman, 2007). University knowledge has the advantage of being isolated from industry competition, and thus, may provide a firm with a more unique know-how and a broad research base (Bercovitz and Feldman, 2007). Previous studies have focused on the relationship between university knowledge and the creation of spin-offs. Landry et al. (2006) used publication to access university knowledge and found two opposing impacts of university knowledge on the creation of spin-offs. On the one hand, researchers with high publication records will consider their publications to be knowledge assets which can be transferred outside the scholarly community, and will be more willing to use their research knowledge to set up spin-offs with industrial partners (Grandi and Grimaldi, 2003). On the other hand, researchers with greater publication assets may spend time concentrating on advancing academic research knowledge, and may be less interested in creating spin-offs.

Patents and patent citations are another widely adopted indicators of university knowledge. Patents represent alternative sources of revenue for university researchers, and this increases their willingness to capture the needs of industry and develop research knowledge which has commercial potential in the private sector (OECD, 2002; Santoro and Chakrabarti, 1999; Landry et al., 2006; Bayona Sáez et al., 2002). University patents are an important signal for firms about the university's highly-applicable knowledge resources. University patents show that universities are able and willing to invest time, effort, and expense in invention application activities, and are willing and able to protect their intellectual property. The business sector and venture capitalists are more likely to become involved with, or invest in, universities which possess more patents, and this facilitates the creation of spin-offs (e.g. Bell and McNamara, 1991; Shane, 2001; Powers and McDougall, 2005). Therefore, even though university researchers with greater knowledge resources may concentrate on their own studies rather than connecting with industry, they are also better able to conduct research projects and generate commercially potential research, and this attracts the business sector to connect with universities to acquire university knowledge in all kinds of knowledge transfer activities.

While many studies explore knowledge flows from universities to industry, Meyer-Krahmer and Schmoch (1998) argue that university-industry knowledge flows in both directions, because university research is not totally basic research, but also applied. Universities and firms may possess their own distinctive knowledge (Bercovitz and Feldman, 2007), and universities also try to obtain industrial knowledge, such as new knowledge and industrial intellectual property, practical experience, application possibilities, and additional insights (Welsh et al., 2008; Arvanitis et al., 2008). Firms with greater knowledge resources have a greater capacity to search for an appropriate academic partner, and industrial knowledge resources also have the advantage of creating bi-directional knowledge flows, which facilitate the transfer of university-industry knowledge. Therefore, the following hypothesis is proposed:

H1-2. Universities' knowledge resources are positively related to university-industry knowledge transfer, including equity-based, contract-based, and relation-based transfer.

H2-2. Firms' knowledge resources are positively related to university-industry knowledge transfer, including equity-based, contract-based, and relation-based transfer.

4.2.1.3 Relationship Resources and Knowledge Transfer

Social relationship resources, such as social networks and trust, are also important for the formation of alliances. When seeking knowledge, firm have to be able to identify "who and how to access" (Tether and Tajar, 2008). An organisation's networking capabilities and social capital enhance its ability to span boundaries (Tushman and Scanlan, 1981; Rosenkopf and Nerkar, 2001), engage with different communities, search for and establish effective relationships with appropriate partners, and select and utilise partners' knowledge (Tether and Tajar, 2008). Past studies which have explored the role of relationship resources in university-industry collaboration have usually focused on the creation of university spin-offs. Scholars indicate that relationship resources enable an organisation to interact across boundaries, link to individuals who can create new knowledge and new ideas, discover new opportunities, and reduce the uncertainty of the knowledge and ideas generated, and that all these are beneficial for successfully establishing university spin-off companies (Debackere and Veugelers, 2005; Wright et al. 2006; Agarwal et al., 2004; López Iturriaga and Martín Cruz, 2008).

Moreover, because of the complex and tacit nature of knowledge, university researchers are not usually good at converting their scientific research outputs into commercial applications or evaluating the commercial value of research applications. Problems of excludability and asymmetry impede university researchers' commercial activities. However, if university researchers are able to network with industry, the connection with the market place reduces the problems of asymmetry, and they are better able to recognise market opportunities, and further facilitate the creation of spin-offs (Szulanski, 2000; Tidd and Trewhella, 1997; Mustar, 1997; Grandi and Grimaldi, 2003; Landry et al., 2006). López Iturriaga and Martín Cruz (2008) explored the antecedents of corporate spin-offs using a sample of 3462 Spanish firms, and they found evidence that firms with social networking were more likely to create cooperative spin-offs, and then new knowledge could be exploited through those spin-offs. A survey of 1554 Canadian university researchers also found that university researchers are more likely to create spin-offs as their social capital assets increase (Landry et al., 2006). Segarra-Blasco and Arauzo-Carod (2008) found that firms with more social networks were more likely to have cooperative R&D

agreements with universities and public research centres. Relationship resources enable a firm to acquire university research with commercial potential in a formal or informal way. In the formal way, relationship resources enable university researchers to find project sponsors or be consultants. Informal personal contacts, such as interaction via phone, email, and visits, are more likely occur at the higher level of relationship resources. In addition, relationship resources enable firms and universities be more likely to discover new market opportunities and further facilitate spin-off creation. Thus, the following hypotheses are proposed:

H1-3. Universities' relationship resources are positively related to university-industry knowledge transfer, including equity-based, contract-based, and relation-based transfer.

H2-3. Firms' relationship resources are positively related to university-industry knowledge transfer, including equity-based, contract-based, and relation-based transfer.

4.2.1.4 Organisational Resources and Knowledge Transfer

Organisational resources refer to assets which are owned and controlled by the organisation (Barney, 1991). Several organisational factors have been found to be related to university-industry collaboration and university spin-off activities, including alliance experience, business support and university support (Acworth, 2008; Muent, 1999; Steffensen et al., 1999; McAdam et al., 2006), university experience (O'Shea et al., 2005; Lee, 1996; Azagra-Caro et al., 2006), university reward system (Lockett and Wright, 2005; Horng and Hsueh, 2005; Siegel et al., 2004), and organisational orientation (Tether and Tajar, 2008).

Compared to traditional manufacturing alliances, technological alliances are more ambiguous and heterogeneous, which makes it more difficult to transfer knowledge in technological alliances. Therefore, alliance experiences are more important for technological alliances (Reuer and Zollo, 2005). Firms with experience of technological alliances are more likely to enter other alliances sooner, because they are more able to reduce uncertainty in communication with the other company and protect their tacit knowledge (Katila and Mang, 2003).

In addition, university encouragement of university-industry cooperation is found to be important to foster R&D cooperation with firms (Azagra-Caro et al., 2006). For example, MIT's support of entrepreneurial activity facilitated its cooperation with industry, and the knowledge transfer led MIT to make a huge contribution to regional economic competitiveness (Acworth, 2008). However, the promotion and tenure policy of universities is usually based on publishing, and university-industry activities are not included, so university researchers may have less interest in collaborating with industry. University scientists and technology transfer officers indicate that the lack of appropriate incentives and reward systems has been a major barrier to university-industry technology transfer (Siegel et al., 2003a, 2003b; Lockett and Wright, 2005; Horng and Hsueh, 2005). Lockett and Wright (2005) offered a more fine-grained insight with a questionnaire survey in the UK, and their results showed that reward systems are more influential than the general presence of incentive routines on spin-off activities (McAdam et al., 2006).

According to TCE, the more firms with experience in a particular activity, the lower the transaction cost, and the more activity will be likely to occur (Leiblein and Miller, 2003; Pisano, 1989; White, 2000; Kasch and Dowling, 2008). When firms have more alliance experience, they are better able to cull experience and knowledge from the alliance, and may be better able to decide on, and handle, the alliance (Reuer and Zollo, 2005). In addition, organisations' behavioural perspectives suggest that routine incentives and rewards enable people to better perform particular activities (Holmstrom, 1979; Jensen, 1993; Lockett and Wright, 2005). Therefore, the organisational resources of a firm and a university can predict their knowledge transfer pattern. When universities and firms attach importance to university-industry knowledge transfer or have university-industry experience, they are more able to build a routine and provide incentives and rewards for university-industry cooperation, and this encourages members to become involved in university-industry knowledge transfer. Hence, the following hypotheses are proposed:

H1-4. Universities' organisational resources are positively related to university-industry knowledge transfer, including equity-based, contract-based, and relation-based transfer.

H2-4. Firms' organisational resources are positively related to university-industry knowledge transfer, including equity-based, contract-based, and relation-based transfer.

4.2.1.5 TTO Resources and Knowledge Transfer

TTOs liaise between academic and business sectors, playing the role of "business coaching" and "stimulating entrepreneurial activity" (Siegel et al., 2004; Powers and

McDougall, 2005; Lockett and Wright, 2005). TTOs are particularly important in the traditionally non-commercial nature of university environments. Since university scientists have a high degree of psychological ownership for their inventions but have relatively little business knowledge, TTOs are able to promote university-industry technological transfer. TTOs are not only useful for saving university researchers' time and effort in evaluating the commercial value of their research and commercialising their findings, but they also provide a link for firms to access university knowledge. They particularly provide great assistance to SMEs in saving the time and costs of patenting, and maintaining a patent over its lifetime (Yusuf, 2008). TTOs can be said to promote licensing (Macho-Stadler et al., 2007; Shane and Somaya, 2007), spin-off companies (Wright et al., 2006; Powers and McDougall, 2005; Lockett and Wright, 2005; Leitch and Harrison, 2005), and knowledge transfers from academics to practitioners (Bekkers and Bodas Freitas 2008; Siegel et al., 2003a; Siegel et al., 2004; Yusuf, 2008). On this basis, with prior research, the following research hypothesis is proposed:

H1-5. Universities' TTO resources are positively related to university-industry knowledge transfer, including equity-based, contract-based, and relation-based transfer.

4.2.2 Resource Dependency, Resource Complementarity and Knowledge Transfer

4.2.2.1 Resource Dependency and Knowledge Transfer

The resource dependency theory assumes that all organisations must establish links with the outside world to obtain the necessary resources for business survival, and that resources and actions carried out by partners in cooperative agreements lead to dependency (Pfeffer and Salancik, 1978; Gray, 1985; Mora-Valentin et al., 2004). The dependency on external resources is the key antecedent which motivates the establishment of inter-firm relationships (Ke and Wei, 2007). This linkage enables partners to exchange the resources and capabilities they need. Since both sides of the cooperative partners contribute equal resources which are beneficial for each other, the two organisations are considered to be inter-dependent; otherwise, a greater volume of resources contributed by one partner would generate greater dependency (Horton and Richey, 1997; Gulati, 1999; Mora-Valentin et al., 2004). According to RBT logic, since universities are more able to provide the resources firms need, it is more attractive for firms to link with them to gain and exploit their resources.

In addition, Pfeffer and Salancik (1978) suggest that firms should manage the dependency by setting up collective structures, integrating, or using a social approach to alter patterns of inter-dependency and establish a negotiated and created environment. According to TCE, a higher level of dependency on a partner makes firms lack control over these resources and raises problems of uncertainty. This is likely to lead to a choice of integration in which the risk is suppressed by shared ownership to gain control over resources. In inter-firm alliances, when the collaborative partner gains more resources and capability from the alliance, it is more likely to become a competitor at the end of the alliance, or when their common enemies are eliminated from the market, vertical integration will be preferred to reduce uncertainty, risk, and opportunistic behaviour (Chen and Chen, 2003). van de Vrande et al. (2009) highlight knowledge dependency, and argue that a dependency on technological knowledge increases the integration level of cooperation governance. A greater dependency on knowledge may cause a larger technological distance, which causes the firm to have a limited capability to absorb its partner's technology, and opportunistic behaviour is caused by information asymmetries and the selection of inferior technologies, which makes it more difficult and costly to write complete contracts. This makes a higher level of integration more favourable. Thus, when universities have a greater volume of resources, firms are more willing to cooperate with them to gain and exploit those resources. Therefore, an equity-based transfer is preferred in order to increase the control over cooperation and reduce risk and opportunistic behaviour. On this basis, the following hypothesis is proposed:

H3. A greater resource dependency (university has a greater volume of resources than firm) in property-based resources (H3-1), knowledge resources (H3-2), relationship resources (H3-3), and organisational resources (H3-4), is positively related to university-industry knowledge transfer in any mechanism, particularly an equity-based transfer.

4.2.2.2 Resource Complementarity and Knowledge Transfer

Resource complementarity refer to a symmetric partnership which jointly uses two sets of heterogeneous resources (Chi, 1994), and the resource complementarity facilitate the formation of an inter-firm alliance (Chen and Chen, 2003; Tjemkes, 2008). Through this means of cooperation, a firm can gain access to desired complementary resources from its partner without possessing the entire bundle of resources and capabilities in a particular domain of activity (Chen and Chen, 2003; Tjemkes, 2008). The sharing of complementary resources among partners enables parties to develop an idiosyncratic resource foundation, which enables synergy creation and provides a strong incentive to maintain the relationship (Lambe et al., 2002; Lin et al., 2009). Gaining access to a partner's respective specialised complementary assets is a key driver for young high-tech firms to set up commercial alliances to use partners' existing assets and capabilities through a division of tasks (Colombo et al., 2006). Tether and Tajar (2008) found that firms are likely to use specialist knowledge providers, such as university and research centres, to complement their own internal innovative activities. Cooperation with a university complements a firm's innovative activities, such as performing its own R&D, sourcing public information, and cooperating with other partners (Veugelers and Cassiman, 2005). The excellent scientific knowledge background and manpower of a university can complement the firm's ability to perform in commercial and technological fields. When the two parties can make up for each other's lack of resources, they are more willing to collaborate and share their resources and knowledge on the basis of mutual reciprocity. Hence, the following hypothesis is proposed:

H4. The resource complementarity between firms and universities are positively related to university-industry knowledge transfer in any mechanism, including equity-based, contract-based, and relation-based transfer.

4.2.3 Transaction Costs and Knowledge Transfer

An alliance includes a series of resource exchange and knowledge exchange activities. The exchange activities involve transaction costs, such as searching, drafting, negotiating, and monitoring to insure against a partner's opportunistic behaviour. Therefore, TCE is applied to explore the alliance formation (Yasuda, 2005; García-Canal et al., 2008; Kasch and Dowling, 2008) and the decision to source technology/innovation (Gooroochurn and Hanley, 2007; McIvor, 2009; van de Vrande et al., 2009). University researchers and entrepreneurs make a decision to collaborate based on the transaction costs involved in the collaboration. Firms will choose to enter an alliance when it can achieve a reduction in their transaction and coordination costs and increase the commitment of the participants. If the alliance carries a greater level of potential opportunism and risk, firms may choose not to collaborate, or collaborate in an integrated form. In addition, the invention disclosure behaviour of university researchers can also be explained with TCE logic. University researchers' choice of invention disclosure is made by evaluating the potential benefits and derivative costs, including licensing income, royalties, individual tenure application, and research project application, patent application fees, effort, and time for innovative invention (Chang et al., 2006). University researchers are encouraged to choose a partner who is likely to generate the highest additional funding for its own research projects (Landry and Amara, 1998). Landry and Amara (1998) compared types of university collaborative research projects, i.e. with industry, with researchers from other universities, and with other institutions (e.g. government agencies, local governments and organised interest groups), and they found that university–industry research collaboration involves greater transaction costs due to a higher level of coordination costs of an additional administrative burden.

4.2.3.1 Asset Specificity and Knowledge Transfer

Asset specificity refers to the asset-specific investments in a partnership. Asset specificity includes human knowledge asset specificity (e.g. highly specialised human skills), physical asset specificity (e.g. specialised facilities, systems, and tools), and dedicated assets (e.g. investment for a specific partner) (Williamson, 1985, 1983). Asset specificity represents a larger investment in a relationship and larger transaction costs when a firm switches to another partner. According to TCE, if a firm contributes a greater level of specific assets to the alliance, it runs the risk of holdup problems, moral hazards, and opportunistic behaviour by the other party in the Williamson's sense of "self-interest seeking with guile". Therefore, it is likely to choose an equity-base alliance or an alliance with a formal contract (Chen and Chen, 2003; Gulbrandsen et al. 2009; Aulakh and Gencturk, 2008; Poppo and Zenger, 2002). Equity-based alliances and straightforward contracts with no exchanged equity, such as licensing and outsourcing agreements, can reduce the incentive to cheat and the risk of opportunistic behaviour when accessing a partner's generic resources (Teece, 1986). Thus, the following hypothesis is proposed:

H5. Asset specificity, including physical asset specificity (H5-1), knowledge asset specificity (H5-2), and dedicated assets specificity (H5-3) is positively related to university-industry knowledge transfer, particularly with equity-based transfer and contract-based transfer.

4.2.3.2 Uncertainty and Knowledge Transfer

Higher uncertainty also increases the transaction costs of exchange activities (Williamson, 1991). Williamson (1985) identifies environmental uncertainty and behavioural uncertainty. Environmental uncertainty refers to unpredictable external changes (Walker and Weber, 1984), and these can be further classified into technological uncertainty and market uncertainty to represent unexpected changes in technologies and markets (Chen and Chen, 2003; Kasch and Dowling, 2008; Cavusgil and Lee, 2006). The highly uncertain and non-codifiable nature of scientific knowledge generates higher transaction costs in the market for this know-how (Veugelers and Cassiman, 2005). Transaction costs arise when the market and technology is more complex, or the market demand and supply are unpredictable, or technology changes quickly. This is because firms need to make more effort in drafting contracts, negotiation, and updating contracts to reduce any opportunistic behaviour on the part of a partner, who may draft the contract for self-interest. In this case, an integrated form of alliance can minimise the transaction costs (Ke and Wei, 2007; Williamson, 1985; Chen and Chen, 2003; Kasch and Dowling, 2008). Moreover, when a partner's behaviour is unpredictable and it is hard to evaluate the alliance performance, opportunistic behaviour and dishonest behaviour can arise, such as cheating, distortion of information, and shirking of responsibility. An alliance with an equity-based mechanism is helpful for reducing the transaction costs by monitoring, enforcing, and regulating the contracts. Empirical studies demonstrate the fact that vertical integration and/or equity-based governance are more likely to arise when there is a greater level of market uncertainty (e.g. Walker and Weber, 1984, 1987; Kale and Puranam, 2004; Kasch and Dowling, 2008) and behavioural uncertainty (e.g. Anderson, 1985; Gatignon and Anderson, 1988; John and Weitz, 1989; Chen and Chen, 2003).

However, some studies have found that market uncertainty and technological uncertainty leads to the use of a less hierarchical form of collaboration. For example, technological uncertainty has been found to lead to more external bio-technological R&D alliances (Pisano, 1990), or more licensing than acquisition (Steensma and Fairbank, 1999). Environmental turbulence has been found to lead firms to prefer non-equity alliances rather than minority holdings, and minority holdings rather than joint ventures (Santoro and McGill, 2005). Less integrated forms have the advantage of being flexible and having a lower level of financial commitment, which enables firms to respond quickly to changing environments, and reduces the potential costs associated with environmental turbulence (Gulbrandsen et al., 2009; van de Vrande et al., 2009). Accordingly, both equity-based alliances and contract-based alliances may arise as uncertainty increases. On the one hand, equity-based collaboration is preferred to reduce a partner's opportunistic behaviour and the transaction costs of updating and monitoring contracts which align technology and market change. On the other hand, market and technology uncertainty make technological results and commercial success more unpredictable. In order to cope with unforeseen contingencies and reduce risk, firms may tend to choose a flexible contract-based mechanism with less financial commitment. In addition, Cavusgil and Lee (2006) found that greater market and technological uncertainty generate environmental turbulence, and relation-based collaboration could enhance the performance of an alliance in terms of stability, strength, and knowledge acquisition under the high pressure of environmental turbulence. On the basis of prior studies, it is posited that, in a higher level of uncertainty, all three types of knowledge transfer mechanisms are more likely to be used to reduce opportunism r and facilitate cooperative behaviour. Hence, the following hypothesis is proposed:

H6. Uncertainty, including market uncertainty (H6-1), technological uncertainty (H6-2), and behavioural uncertainty (H6-3) is positively related to university-industry knowledge transfer in any mechanism, including equity-based, contract-based, and relation-based transfer.

4.2.4 Knowledge Transfer and Knowledge Transfer Performance

R&D cooperation with other organisations has been found to be an efficient way to develop a firm's R&D capability (George et al., 2002; Kelley and Rice, 2002; Okamuro, 2007). By sharing costs and risk, contributing different resources and technological know-how, and jointly developing new technological knowledge and innovation, firms are more likely to keep pace with technological advancement in the marketplaces (Chang, 2003). Innovative firms particularly need to cooperate with other firms, suppliers, customers, universities, and R&D institutions to enhance their innovative performance (Freel, 2000; Chang, 2003). Cooperation with R&D institutions has been found to facilitate French manufacturing firms' patenting performance, and an investigation into the Japanese area also supports the fact that cooperative R&D projects of SMEs with universities and public research institutes are more likely to have technological success (Miotti and Sachwald, 2003; Okamuro, 2007). Similarly, Arita et al. (2006) compared the R&D cooperation performance of Japanese SMEs with different partners, and found that R&D cooperation with "universities and research institutes" and with "cross-industry exchange organisations" particularly had a stronger positive effect on firms' growth, whereas R&D cooperation with suppliers and customers did not contribute to firms' growth.

However, a university-industry R&D collaboration may not promote the firm's overall performance. George et al. (2002) found that although R&D collaborations with universities facilitated biotechnology firms to earn more patents, it did not improve their new product development performance and financial performance. A survey in Japan also showed that firms' R&D projects with universities are effective in producing patent applications, but do not necessarily facilitate new product development (Kodama, 2008). Therefore, although collaborating with a university may not have a direct effect on a firm's profits, it has more of a direct impact on the firm's innovative and commercial performance (Jiang and Li, 2009). From the resource perspective, university-industry cooperation provides a connection between business sectors and academic institutes to complement each other's resources. By collaborating with a university, a firm can access the university's research manpower, research results, and facilities (Peters and Fusfeld, 1982; Okamuro 2007), which facilitates the generation of scientific knowledge and conducts early-stage development, which initiates technological invention (Yusuf, 2008). From the perspective of knowledge transfer, universities provide superior and diverse knowledge resources, and the interaction and collaboration between the business sector and academic sector facilitate the transfer, sharing, and creation of critical information and knowledge, which in turn, increases the knowledge transfer performance. Therefore, the following research hypothesis is proposed:

H7. University-industry knowledge transfer is positively related to a firm's knowledge transfer performance, including knowledge acquisition, knowledge creation and commercial success.

Branstetter and Sakakibara (2002) indicate that the design of R&D cooperation plays a more important role than R&D input in generating technological performance. The firm's knowledge transfer performance may vary with different forms of university-industry linkages (Giuliani and Arza, 2009). The relationship between knowledge transfer performance and the three types of knowledge transfer mechanisms is discussed below.

4.2.4.1 Equity-Based Transfer and Knowledge Transfer Performance

University spin-off is one knowledge transfer channel between universities and industry (Bekkers and Bodas Freitas, 2008). The number of spin-off companies created is widely used as an indictor of university performance when linked with industry (e.g. Landry et al., 2006; Powers and. McDougall 2005; O'Shea et al., 2005; Lockett and Wright 2005; Chang et al., 2006; Wright et al., 2006). With joint research between top university professors and top firms' researchers, university spin-off activities were found to particularly promote and commercialise academic breakthroughs (Zucker et al., 2002; Bekkers and Bodas Freitas, 2008).

Equity-based alliances have been found to improve the international alliance performance of SMEs with a higher level of process controls and commitment (Nakos and Brouthers, 2008). A joint spin-off is a specific collaborative form involving equity agreements. The control systems of an equity-based alliance integrate and align different organisational objectives and individuals among alliance members (Siders et al., 2001). Alliance partners within an equity-based alliance usually expect the alliance to be a long-term relationship, and this increases their willingness to maintain the relationship, and thus, reduce the opportunism behaviour of all the members (Muthusamy and White, 2005; Nakos and Brouthers, 2008). According to TCE, equity-based alliances with formal arrangements create high exit costs, prevent the opportunistic behaviour of member firms, and establish a mutual commitment to resources. They strengthen and stabilise alliances and make the partnership last longer (Pangarkar, 2003, Chen and Lin, 2004; Bönte and Keilbach, 2005; Okamuro, 2007). Collaboration with an integrated form has been found to effectively facilitate knowledge transfer, especially tacit knowledge (Cantwell and Colombo, 2000; Sampson, 2004; van de Vrande, et al., 2009). This is because equity arrangements involve tighter and more active interactions, more mutual resource investment, and greater integration of the partners. They also provide an effective setting for the discovery and learning of new knowledge, which leads to a greater general knowledge transfer performance (Chen and Lin, 2004).

On the contrary, Okamuro (2007) argues that equity joint venture R&D collaboration may lead to a worse R&D performance because of a lack of flexibility. He examined the patent data of Japanese manufacturing SMEs and found that formal R&D projects within a joint venture have no significant impact on technological success, and even show a weak negative influence on the commercial success of R&D cooperation. Accordingly, it is posited that an equity-based transfer may have two opposing effects on knowledge transfer performance. On the one hand, equity-based integration with equity bounding facilitates knowledge transfer activities with a formal control system and mutual commitment (Nakos and Brouthers, 2008, Das and Teng, 2002), which increases active interactions, promotes the willingness and efficiency of alliance members to share resources, knowledge, and skills, and thus generates a better knowledge trasnfer performance. On the other hand, an equity-based mechanism impedes knowledge transfer performance due to its inflexibility, rigidity, and cultural differences. Hence, the following hypothesis is proposed:

H7-1. Equity-based transfer is positively (H7-1a) or negatively (7-1b) related to knowledge transfer performance, including knowledge acquisition, knowledge creation, and commercial success.

4.2.4.2 Contract-Based Transfer and Knowledge Transfer Performance

Most university–industry collaborative activities involve formal agreements rather than equity arrangements. Joint research and contract research have been identified as being important channels of university–industry knowledge transfer (Kingsley et al., 1996; Monjon and Waelbroeck, 2003; Bekkers and Bodas Freitas, 2008). Contract research is a popular form for a firm to access the knowledge of university scientists, and utilise the unique capability of a university to work for commercial benefit, particularly when the technology is still in the early stage of invention (Lee and Win, 2004; Poyago-Theotoky et al., 2002; Wright et al., 2008). Otherwise, joint research enables partners to contribute and share R&D resources to conduct specific research, and it is sometimes given more priority than contract research in knowledge transfer for both industrial scientists and university scientists (Okamuro, 2007; Meyer-Krahmer and Schmoch, 1998; Bekkers and Bodas Freitas, 2008). Hiring university researchers is another common method to effectively transfer university knowledge to firms, especially for the chemistry or biotechnology industry (Zucker et al., 2002; Gübeli and Doloreux, 2005). Lee and Win (2004) examined university-industry joint venture, licensing, joint R&D projects, contract research, seminars, and conferences activities of Singapore research centres with a case study. They found that "joint R&D projects" are an efficient way to transfer knowledge because they ensure the high commitment of industry and encourage involvement with cooperative partners. Otherwise, licensing is an efficient way to transfer knowledge when the knowledge is more explicit.

The adoption of a contract-based alliance has been found to improve knowledge transfer between inter-firm partners (Cavusgil and Lee, 2006). Contract-based alliances are particularly efficient in smoothing the transfer of explicit knowledge (Chen and Lin, 2004). According to TCE, a formalised contract ensures that the agreed transactions will be met (Ring and Van de Ven, 1992; Cavusgil and Lee, 2006). A formal contract represents a legally binding agreement which explicitly states each party's obligations, and an agreement with formal rules and procedures is helpful for handling various unforeseeable situations. Therefore, it provides a safeguard mechanism to govern business transactions through decreasing uncertainty and risk of partnership (Lusch and Brown, 1996; Lui et al., 2009). This relationship is extended to knowledge transfer activities. A formal contract increases the control of information sharing, which reduces the risk that knowledge transfer may exceed the scope intended by the partners, and then enhances knowledge transfer performance. Hence, the following hypothesis is proposed:

H7-2. Contract-based transfer is positively related to knowledge transfer performance, including knowledge acquisition, knowledge creation, and commercial success.

4.2.4.3 Relation-Based Transfer and Knowledge Transfer Performance

Hagedoorn et al. (2000) argue that a large proportion of university-industry interactions might be informal. Informal personal contact is ranked as being the most important university-industry knowledge transfer channel for university researchers (Arvanitis et al., 2008). Compared to interaction based on formalised and legally-binding agreements, a relation-based mechanism focuses on informal relational norms (Cannon et al., 2000). Informal interactions such as personal contacts, meetings, participation in conferences, and co-authoring occur without formal arrangements, and are therefore more flexible. A relation-based mechanism has been found to improve inter-firm relationships (Poppo and Zenger, 2002; Styles and Ambler, 2003). Vandaele et al. (2007) indicate that both contract-based and relation-based mechanisms are beneficial for alliance performance because they reduce uncertainty, while contract-based mechanisms are established ex ante and relation-based mechanisms continue over time. Sherwood and Covin (2008) found that communication between university–industry technological experts via e-mail, telephone, visits, and meetings increases the acquisition of tacit and explicit knowledge from universities, whereas communication through formal teams has no effect on knowledge acquisition. Cavusgil and Lee (2006) analysed 184 business alliances and found that a relation-based mechanism is more effective and influential than a contract-based mechanism in enhancing alliance stability, alliance strength, and knowledge transfer between partners. This is because trust is involved in a relation-based mechanism, and this reduce functional conflict and stagnation, and thus increases the productivity of performance. Although a relation-based mechanism is not legally bound by a formal arrangement, the social processes and stronger ties enhance trust and promote norms of flexibility and solidarity, and thus, it facilitates the exchange of knowledge and information. On this basis, the following hypothesis is proposed:

H7-3. Relation-based transfer is positively related to knowledge transfer performance, including knowledge acquisition, knowledge creation, and commercial success.

4.2.5 Resources and Knowledge Transfer Performance

RBT assumes that a firm's unique bundle of assets and resources determine its success (Wernerfelt, 1984). Tangible and intangible resources contribute to the creation of competitive advantage and internal capabilities, and improve a firm's value creation and performance in a competitive and changeable environment (Baum et al., 2001; Lee et al., 2001; Leitch and Harrison, 2005). Resources can originate internally or be acquired externally, and an alliance arises when an organisation engages in an exchange with others to obtain resources (Lavie, 2006; Chen, 2002).

University characteristics and industry characteristics have usually been examined respectively on their impact on university-industry collaborations. A group of studies focused on university characteristics, and found that a university's federal funds, credibility and reputation, quality of faculty, patents, publications, technological transfer experience, TTOs, and orientation of applied research improve a university-industry collaboration (Bagchi-Sen, 2007; Rothaermel and Thursby, 2005;

Lockett and Wright, 2005, O'Shea et al., 2005; Arvanitis et al., 2008; van Rijnsoever et al., 2008; Azagra-Caro et al., 2006; Price et al., 2008). In recent years, an increasing number of studies have explored the effects of industry characteristics and found that firms' R&D expenditure/funding, size, research capability, manufacturing capability, CEO's capability, relationship and networks, team structure, technological familiarity, technological agreements, and experience relate to university-industry collaboration (Bercovitz and Feldman, 2007; Li and Chen, 2009; Kodama, 2008; Motohashi, 2005; Giuliani and Arza, 2009; Sherwood and Covin, 2008; Segarra-Blasco and Arauzo-Carod, 2008; Østergaard, 2008; Stuart et al., 2007).

These resource inputs from industries and universities increase university researchers' R&D productivity. Chang et al. (2006) applied a scientific–economic framework to explore the determinants of the academic innovation of higher educational institutes (HEIs), and the results showed that universities with more intellectual property, managerial capability, external industrial partnerships, and entrepreneurial orientation had a better performance in generating patents, licensing, and university spin-offs. In terms of the effect of university/industry characteristics and resources, increasing university research outputs strengthen the university knowledge source, which can be transferred to industry. For example, Baba et al. (2009) found that collaborating with university Pasteur scientists with greater publication and patent records particularly increased firms' R&D productivity in terms of the number of patent applications. In addition, the resources of university and industry can smooth the process of knowledge transfer between university and industry. Horng and Hsueh (2005) found that the provision of rewards for university faculties involved in technological transfer, resource allocation, and the marketing experience and skills of TTOs, improve efficiency in transferring scientific knowledge from universities to firms. The knowledge from university to industry was also found to improve regional economic performance with a higher level of firms' capital intensity, labour, R&D ability, R&D in universities, industrial grants per researcher, and entrepreneurship (Mueller, 2006). Prior research shows that the resources contributed by both university and industry increase the university's research performance, and these resources also facilitate knowledge transfer from university to industry. Therefore, the following hypothesis is proposed:

H8. Universities' resources are positively related to knowledge transfer performance, including knowledge acquisition, knowledge creation, and commercial success.

H9. Firms' resources are positively related to knowledge transfer performance, including knowledge acquisition, knowledge creation, and commercial success.

4.2.5.1 Property-Based Resources and Knowledge Transfer Performance

Industrial grants have been identified as being critical research resources for university researchers. Blumenthal et al. (1996) analysed a sample of 2052 faculties at 50 universities in the life sciences field, and found that industry funded faculties are more commercially productive in terms of patent applications and new products brought to the market. Similarly, a survey in Norway showed that university researchers with industry grants demonstrated better research productivity, such as publishing and patents (Gulbrandsen and Smeby, 2005). The positive effect of industry funds on university researchers' publication rates and entrepreneurial activities was also supported in a Belgian survey (Van Looy et al., 2004). Boardman and Ponomariov (2009) surveyed 1643 US university researchers, and found that university researchers with industry grants have a better performance of academic activities (e.g. co-authoring referred papers, placing students and post-docs in industry jobs) and entrepreneurial activities (paid consultancy, patents, copyrights, commercialisation). University researchers with industry grants are more able to acquire funding from other places, and are therefore more productive in terms of the university's patent citations (Owen-Smith, 2003). Industrial grants and facilities also reduce development costs and cycle time, which increases the potential of research and the quality of university researchers' work, thus generating more innovation invention for their industrial partners (Numprasertch and Igel, 2005).

Although previous studies have produced evidence that industry grants facilitate the formation of university-industry collaboration and university researchers' performance, fewer researchers have explored the relationship between industry grants and the firm's own R&D productivity when it collaborates with a university. Kodama (2008) found that firms which spend more on R&D in university-industry projects have a greater R&D outcome, including patent applications, the launching of new products, and the development of new processing technologies put into practical use. Firms' research investment in university-industry collaboration enhances their knowledge and innovation output in two ways. Firstly, university researchers' research outputs are the source of firms' innovation invention. Industry grants provide motivation and resources for university researchers to conduct more experiments and

R&D projects, and to meet the needs of industry and devote themselves to research with a commercial potential. Moreover, when firms provide more funding and facilities, they have more power to influence and control the processes and patterns of university-industry knowledge transfer and knowledge exchange activities to meet industry needs, and therefore, they generate a better knowledge transfer performance. Thus, the following hypothesis is proposed:

H9-1. Firms' property-based resources are positively related to knowledge transfer performance, including knowledge acquisition, knowledge creation, and commercial success.

On other hand, universities' R&D funding and facilities may decrease firms' knowledge transfer performance. Bougrain and Haudeville (2002) found that the industry innovation projects with a public subsidy (e.g. R&D projects with universities) had a negative effect on the success of innovation projects. Their results revealed that the probability of project success may decrease when firms obtain additional public subsidies in university-industry projects. Public subsidies create a problem of moral hazard because the firms may reduce their own R&D expenditure and efforts, or select risky projects with the subsidies, which may lead to lowering the possibility of success (Okamuro, 2007). Okamuro (2007) analysed 255 collaborative projects of Japanese manufacturing SMEs, and they also found that cooperative projects with public subsidies did not generate technological success (e.g. patent), and even showed less commercial success (e.g. sales growth). Accordingly, it is posited that university property-based resources impede knowledge transfer performance. Although university R&D funding and R&D facilities provide researchers with more resources to conduct R&D activities, which will create more knowledge and commercial outputs, firms may select risky projects, or projects which are still in the early stage of development, or be free-riders, which will have a negative impact on knowledge transfer performance. Thus, the following hypothesis is proposed:

H8-1. Universities' property-based resources are negatively related to knowledge transfer performance, including knowledge acquisition, knowledge creation, and commercial success.

4.2.5.2 Knowledge Resources and Knowledge Transfer Performance

University researchers are critical sources for firms to access knowledge and talented manpower for the development of sophisticated technologies (Powers and McDougall, 2005). Several empirical studies have demonstrated that the scientific knowledge and capability of university researchers are beneficial for various industrial innovation productivity cross-fields, such as patent development for the bio-technology industry (Zucker et al., 2002; Gittelman, 2007), patents for life science sectors (Murray, 2002), patents and publication citations of life science sectors (Owen-Smith et al., 2002; Owen-Smith and Powell, 2004), innovation of the nanotechnology industry (Meyer, 2006, 2007), publications and patents of the advanced materials industry (Baba et al., 2009), patent citation of the high-technology industry (Fischer and Varga, 2003), new processes and product innovation of high-technology industries (Mansfield and Lee, 1996).

Baba et al. (2009) examined 455 Japanese advanced materials and medical devices firms, and the results showed that a collaboration with Pasteur university scientists (scientists with strong publications and patents) and Edison university scientists (scientists with a strong patents background) enhance firms' patent application. University researchers concentrate on basic science research and create numerous technological advances (Rosenberg and Nelson, 1994). A university with more knowledge resources, such as a pure science publishing background, an applied science patenting background, or a qualified research team, can be seen to be willing to take considerable time, effort, and resources on innovation invention. Thus, it will be more likely be successful in its technological transfer efforts with industry. Hence, the following hypothesis is proposed:

H8-2. Universities' knowledge resources are positively related to knowledge transfer performance, including knowledge acquisition, knowledge creation, and commercial success.

A firm's specific knowledge is the foundation of its innovation output (Sherwood and Covin, 2008; Asheim and Coenen, 2005; Moodysson et al., 2008; Baba et al., 2009). However, relatively few studies have explored the role played by a firm's knowledge resources in university-industry knowledge transfer activities, and there is a lack of research which examines the relationship between a firm's performance and its knowledge transfer performance. Giuliani and Arza (2009) examined the university-industry collaboration of the wine industry in Chile and Italy. Their results demonstrated that firms with stronger knowledge bases are more capable of seeking and exploiting external knowledge from universities, and this creates valuable university-industry linkages, with a higher potential to diffuse knowledge to other firms. Baba et al. (2009) argue that knowledge transfer is a two-way interaction between university and industry researchers. They emphasise the role played by industrial knowledge bases in innovation, and suggest that further studies should look at innovation dynamics between university and industry with a bilateral model. To achieve successful R&D cooperation, a firm has to have the knowledge to undertake collaborative R&D activities (Maine and Garnsey, 2007). "Acquiring knowledge from external sources" is not enough for firms to enhance their innovative performance (Jiang and Li, 2009). They must also have the ability to integrate existing knowledge into new knowledge, and convert this knowledge into production (Nonaka and Takeuchi, 1995; Cloodt et al., 2006). Accordingly, when firms have more knowledge resources, they are more capable of searching and connecting to universities, of acquiring and absorbing the knowledge generated from university partners, of conducting R&D projects with bilateral interaction, and of integrating the acquired knowledge with their existing knowledge. Therefore, they are more likely to generate new knowledge to bring commercial potential. Hence, the following hypothesis is proposed:

H9-2. Firms' knowledge resources are positively related to knowledge transfer performance, including knowledge acquisition, knowledge creation, and commercial success.

4.2.5.3 Relationship Resources and Knowledge Transfer Performance

Alliances exist in social contexts, and relationship resources not only play an intermediary role to facilitate alliance creation, but also smooth the interaction of alliances. Networks between different communities help firms to identify who to access and how to make contact, and enables firms to seek out and forge effective relationships with appropriate partners (Tether and Tajar, 2008). As for university researchers, their networks with faculties, other universities, scientific bodies, and industry, increase researchers' competitive advantages to gain research funding, prizes, and better careers (Hagstrom, 1966; Bourdieu, 1974; Latour and Woolgar, 1979; Rijnsoever et al., 2008). West and Noel (2009) examined the networking activities of firms' CEOs in technology-based firms, and the results showed that CEOs' networking activities are predictors of the overall performance of new venture companies. Hansen (1999) found that firms' product development teams with strong ties with collaborative partners are more cost effective in searching for new information and transferring complex and tacit knowledge. Individuals who have a strong relationship with other groups are more likely to possess new and valuable information, and the linkages between different groups facilitate the diffusion of new information (Rogers, 2003; Rogers and Kincaid, 1981; Granovetter, 1973; Burt, 1997, West and Noel, 2009).

Trust and commitment are other relationship factors to improve the quality and performance of an alliance. A research project is found be more likely to achieve technical success when the R&D alliance has a longer duration and a stable ownership relation (Bizan, 2003). Empirical studies show that trust, familiarity, and commitment improve university-industry relationships, and generate a better university-industry collaboration performance (Thune, 2007; Plewa and Quester, 2007). According to TCE, trust reduces negotiation costs and the uncertainty which may arise from a partner's opportunistic behaviour. Therefore, trust decreases conflict between different cultures and different systems, and improves collaborative behaviour. From the knowledge perspective, mutual trust and commitment enable partners to make a fast and accurate response to potentially valuable and important information through the network. (Kale et al., 2000; Kwon, 2008). In addition, trust between partners leads to better communication and closer personal interaction, and frequent interaction facilitates the exchange of knowledge and information, which decreases conflict and misunderstanding and increases the quality of the information and knowledge acquired from partners. Trust between partners has been found to help industries to acquire more knowledge from universities (Sherwood and Covin, 2008). The relationship resources of universities and industries enable them to cross boundaries and seek relationships with appropriate partners, to access knowledge, information, and opportunities, share and exchange knowledge, resources, and innovation invention. This leads to greater knowledge transfer performance. Thus, the following hypotheses are proposed:

H8-3. Universities' relationships resources are positively related to knowledge transfer performance, including knowledge acquisition, knowledge creation, and commercial success.

H9-3. Firms' relationships resources are positively related to knowledge transfer performance, including knowledge acquisition, knowledge creation, and commercial success.

4.2.5.4 Organisational Resources and Knowledge Transfer Performance

A new product with superior technology has been found to not always lead to commercial success (Fassin, 2000; Tidd and Bessant, 2009). It is a long way from inventing technology to applying for a patent, and from acquiring the patent to developing the new product. The business process involves complex systems including policies and supporting organisational systems (O'Shea et al., 2007, Acworth, 2008). A well-organised organisation plays a vital role in facilitating knowledge transfer. For example, experienced universities and industries are more likely to be able to find an appropriate partner and an appropriate structure to acquire knowledge and deal with feedback from partners in technology transfer activities (Owen-Smith and Powell, 2003). In their survey of Japanese manufacturing, Okamuro (2007) found evidence that cooperative R&D experience led to successful cooperative R&D projects. Alliance experience contributes to alliance performance with the benefit of a learning curve effect (Zollo et al., 2002; Giuliani and Arza, 2009). According to RBT, alliance experience is a tangible resource to create competitive advantage, because it enables a firm to learn more efficiently from its partner, manage the alliance process in complex conditions, understand collaborative possibilities, and know what to avoid, as well as being aware of the opportunities of environmental development (Kale et al., 2002; Sherwood and Covin, 2008; Reuer and Zollo, 2005). From the knowledge transfer perspective, firms with alliance experience can more easily recognise, understand, and internalise partners' tacit and explicit knowledge, and this leads a knowledge-seeking firm to choose an appropriate structure to acquire the desired knowledge from the current holder, and to be more successful in acquiring technological knowledge from its partner (Lane and Lubatkin, 1998; Zahra and George, 2002; Sherwood and Covin, 2008).

A clear policy which supports faculties in becoming involved in technological transfer with greater rewards is also a kind of organisational resource. Empirical studies indicate that a clear university policy, which supports faculties to become involved in university-industry knowledge transfer activities, enhances university researchers' efforts to invent and become involved with industry, and thus, it generates more licenses (Horng and Hsueh, 2005; Lockett and Wright, 2005; Friedman and Silberman, 2003). Chang et al. (2006) argue that university researchers' choice of invention disclosure is based on a costs and benefits analysis.

When the benefits of invention exceed the costs, university faculties are more likely to engage in invention disclosure behaviour with industry. Therefore, the more the incentives which facilitate university faculties, the greater effort and time researchers apply to research and inventions, and commercial activities (Di Gregorio and Shane, 2003; Chang et al., 2006). In view of this, firms and universities with university-industry collaborative experience are more able to understand their partner's institutional norms, and are more able to efficiently manage the collaboration process and knowledge transfer activities. In addition, the support and rewards of a university-industry collaboration improve researchers' efforts in technology invention and engagement in knowledge transfer with partners, and facilitate knowledge exchange and new knowledge creation. Therefore, the following hypotheses are proposed:

H8-4. Universities' organisational resources are positively related to knowledge transfer performance, including knowledge acquisition, knowledge creation, and commercial success.

H9-4. Firms' organisational resources are positively related to knowledge transfer performance, including knowledge acquisition, knowledge creation, and commercial success.

4.2.5.5 TTO Resources and Knowledge Transfer Performance

TTOs are specific intermediaries which align and assist universities in transferring knowledge to industry. A series of studies have explored the role of TTOs, and researchers agree that TTOs assist the setting up of partnerships between businesses and universities, encourage university faculties to disclose their inventions, promote universities to manage technological diffusion and knowledge transfers, unitise the basic knowledge generated by researchers, and make inventions commercialisable (O'Shea et al., 2007; Yusuf, 2008; Siegel et al., 2004; Chang et al. 2006; Lockett et al., 2003, Lockett and Wright, 2005; Bayona Sáez et al., 2002). Previous empirical studies focused on the benefits of TTOs for university outputs, and found that TTOs increase the number of university invention disclosures (Thursby et al., 2001) and the number of licenses (Friedman and Silberman, 2003). Chang et al. (2006) found that the scale of full-time employees in TTOs (namely intellectual property managerial capability) increases licensing incomes and incubation creation. However, they also found that larger TTOs may not necessarily yield greater patent creation. TTOs are critical instruments to reduce the asymmetry of information problems between universities and industries, typically encountered in the scientific knowledge market (Macho-Stadler et al., 2007). Sufficient TTO resources, such as scale, technical skills, marketing skills, and negotiating skills, can effectively support the transfer of knowledge to industry (Horng and Hsueh, 2005). TTOs are particularly beneficial for SMEs. Because the application and maintaining of a patent is costly, matchmaking, and needs a great deal of time and effort, and SMEs usually lack resources and the ability to deal with patenting activities, TTOs are useful in saving time and money on intellectual property activities for them (Yusuf, 2008). When TTOs possess more staff and skills, they are capable of coping efficiently with knowledge transfer activities, such as encouraging university faculties to disclose their inventions to industry, exploiting the commercial potential of technological inventions, helping industry to deal with the intellectual property issue, which enables firms to access and make the most of university inventions. On this basis, the following hypothesis is proposed:

H8-5. Universities' TTO resources are positively related to knowledge transfer performance, including knowledge acquisition, knowledge creation, and commercial success.

4.2.6 Resource Dependency, Complementarity and Knowledge Transfer Performance

4.2.6.1 Resource Dependency and Knowledge Transfer Performance

The research has not come to a clear conclusion about the relationship between dependency and cooperation outputs. The empirical results of most studies which examine the relationship between dependency and alliance satisfaction are diverse. Kotter (1979) found that high dependency leads to partners being dissatisfied because dependency creates a threat and uncertainty to an organisation's survival and autonomy. On the other hand, Lewis and Lambert (1985) argue that high dependency represents a greater contribution to the collaboration, and satisfaction with partners increases as their perceived contribution increases. A positive relationship between dependency and alliance satisfaction is supported in a study by Escribá and Menguzzato (1999), who indicate that greater dependency results in more of a contribution from the partner, and the more inputs a partnership generates, the greater the performance outcomes, and this leads to greater satisfaction. Otherwise, some studies have found that dependency has no significant effect on alliance satisfaction (e.g. Gray, 1985; McDonald and Gieser, 1987; Blankenburg et al., 1999). Only a small amount of literature has explored the role of dependency in university-industry cooperation. Mora-Valentin et al. (2004) examined the impact of dependency on the performance of R&D cooperative projects between Spanish firms and research organisations. Their results demonstrated that, although dependency has no significant direct effect on the success of R&D collaboration, it has an indirect effect on R&D success through other determinants factors, such as commitment, trust, and reputation.

According to RET, the aim of an alliance is to gain control over critical resources. When the inter-dependency is asymmetric, the dependent partner has more power to control and influence the other partners to comply with its requests (Ke and Wei, 2007). As a result, it is posited that resource dependency has two opposing effects on university-industry knowledge transfer performance. On the one hand, a firm's dependency on university resources improves knowledge transfer performance because the firm perceives the greater contribution made by its university partner, and is therefore more satisfied with the knowledge transfer activities. Furthermore, when the university is in a stronger resource position, in order to secure access to those resources, a firm may be more vulnerable to sharing industrial knowledge and complying with requests from its partner, and industrial knowledge may improve the commercial value of university intentions. On the other hand, resource dependency on its university partner reduces the firm's autonomy and control over research projects. The academic partner may be inclined to comply less to meet industrial targets, and academic-orientated research may decrease the firm's interest in putting efforts into knowledge transfer, and thus decrease the knowledge transfer performance. Therefore, the following hypothesis is proposed:

H10. Firms' dependency on university resources are positively (H10a) or negatively (H10b) related to knowledge transfer performance, including knowledge acquisition, knowledge creation, and commercial success. Resource dependency includes property-based resource dependency (H10-1), knowledge resource dependency (H10-2), relationship resource dependency (H10-3), and organisational resource dependency (H10-4).

4.2.6.2 Resource Complementarity and Knowledge Transfer Performance

Resource complementarity which jointly use two sets of resources usually yield a higher total return (Chi, 1994). Resource complementarity between firms have been identified as being an important factor in driving the formation of an alliance (Hamel, 1991; Hill and Hellriegel, 1994; Shan et al., 1994; Chen and Chen, 2003). Bayona Sáez et al. (2002) indicate that R&D collaboration between different types of organisations with complementary resources is the foundation of innovation invention. Several empirical studies have found that resource complementarity improve the alliance's performance, such as enhancing alliance stability, creating greater synergy, and increasing the technical success of international research collaborative projects (Bizan, 2003; Park and Ungson, 2001; Kale et al., 2000; Lambe et al., 2002; Tjemkes, 2008). According to the resource dependency theory, when the resources contributed by both partners are complementary, there is a low risk of mutual exploitation, and this makes the alliance sustainable (Chen and Chen, 2003). Through collaboration, firms can complement their knowledge and strengthen their capabilities by exploiting universities' scientific knowledge (Giuliani and Arza, 2009). The experience and expertise of firms are particularly important for universities to generate commercial research and profits in a historically non-commercial environment (Lambert, 2003; Lockett and Wright; 2005). Resource complementarity enable the partners to share their different knowledge to create synergistic benefits, and the exploitation of complementary knowledge also generates more new knowledge and inventions. On this basis, the following hypothesis is proposed:

H11. Resource complementarity between firms and universities are positively related to knowledge transfer performance, including knowledge acquisition, knowledge creation, and commercial success.

The following **Table 4.1** summarises and lists out the hypotheses developed in this chapter.

Table 4.1 Summary of Research Hypotheses

	University-Industry Knowledge Transfer	Knowledge Transfer Performance
Knowledge Transfer		**H7 +**
Equity-based Transfer		H7-1a + H7-1b (-)
Contract–based Transfer		H7-2 +
Relation-based Transfer		H7-3 +
University Resources	**H1** +	**H8** +
Property-based Resources	H1-1 +	H8-1 (-)
Knowledge Resources	H1-2 +	H8-2 +
Relationship Resources	H1-3 +	H8-3 +
Organisational Resources	H1-4 +	H8-4 +
TTO Resources	H1-5 +	H8-5 +
Firm Resources	**H2** +	**H9** +
Property-based Resources	H2-1 +	H9-1 +
Knowledge Resources	H2-2 +	H9-2 +
Relationship Resources	H2-3 +	H9-3 +
Organisational Resources	H2-4 +	H9-4 +
Resource Dependency	**H3** +	**H10a** + **H10b** (-)
Property-based Resources	H3-1 +	H10-1 +
Knowledge Resources	H3-2 +	H10-2 +
Relationship Resources	H3-3 +	H10-3 +
Organisational Resources	H3-4 +	H10-4 +
Resource Complementarity	**H4** +	**H11** +
Asset specificity	**H5** +	
Physical asset specificity	H5-1 +	
Knowledge asset specificity	H5-2 +	
Dedicated assets specificity	H5-3 +	
Uncertainty	**H6** +	
Market uncertainty	H6-1 +	
Technological uncertainty	H6-2 +	
Behavioural uncertainty	H6-3 +	

Note: +: Positive relationship; (-): negative relationship

Chapter 5 Methodology

5.1 Data Collection

The sample in this study consists of biotechnology firms engaged in collaborative partnerships with universities and academic research institutes. Universities and research institutes are particularly the primary source of basic science research for the biotechnology industry to discover the potential commercial value of academic research (Zucker et al., 1998, Quintana-Garci and Benavides-Velasco, 2004). The biotechnology firms are members who have a partnership with university biotechnology departments or *Innovation and Incubation Centres,* which have been set up in university campuses to facilitate the transfer of knowledge and technology between firms and universities. In order to broaden the scope of the collaborative partnerships with other academic research institutes, such as *Academia Sinica*, the *National Health Research Centre*, the *Industrial Technology Research Institution* and so on, the questionnaire also delivered to the biotechnology firms listed in "Taiwan's Biotechnology Industry Directory 2010" which is dedicated to human pharmaceuticals, veterinary products, medical contracts research/manufacturing, materials and equipment supply, diagnostics, including drug delivery and rational drug design, and biotechnology-orientated chemical firms.

The questionnaire was pre-tested by means of a pilot study with 7 managers of the biotechnology industry. The pilot study was used to modify to clarify the unclear items in the scales. The revised questionnaires were further sent via post to managers responsible for university-industry collaboration affairs (e.g. CEOs, R&D managers, project managers). 1316 questionnaires were sent in September 2010, and the target included 219 biotechnology firms which were in partnership with university biotechnology departments and *Innovation and Incubation Centres,* as well as other 1097 biotechnology firms listed in "Taiwan's Biotechnology Industry Directory 2010". Follow-up phone calls and letters were used to check the progress after two weeks.

Managers and R&D managers of 1316 firms were contacted by telephone in order to establish whether their company had collaborated with an academic institution for research development. 412 of them said that they had been involved in collaboration with academic institutions. In order to increase the response rate, respondents were advised that they would receive a gift voucher for NT100 (£2.5) on receipt of their replies. A total of 153 responses were received. A critical standard was set to define the valid responses. A questionnaire with more than 15 items marked continually with the same score was deemed to be invalid. Although using a critical standard to discard invalid questionnaires reduces the total number of responses, it improves the quality of the remainder. In this case, 8 responses were eliminated using this criteria. Finally, a total of 145 valid questionnaires were used for analysis from the 412 firms which had experience of collaborating with academic institutions. This represents a useable response rate of 35.19%.

5.2 Measures

5.2.1 University-Industry Knowledge Transfer Mechanisms

Three mechanisms of university-industry knowledge transfer were identified in this study: equity-based transfer, contract-based transfer, and relation-based transfer. The equity-based transfer refers to the collaboration and knowledge transfer involves equity participation and spin-off activities with academic partners. Contract-based transfer emphasises the use of a formalised, legally binding agreements or contracts to govern the collaboration and knowledge transfer. The relation-based transfer refers to the collaboration and knowledge transfer based on neither equity exchange nor formal contract, but on informal interaction.

The equity-based transfer was constructed as a dummy variable where 1 indicated "setting up a joint venture cooperate spin-off with academic research institutes or researchers", and 0 indicated otherwise. Contract-based transfer includes the knowledge transfer mechanisms based on formal agreements or contracts, such as licensing, joint research, contract research, consulting, training, and researcher mobility. Licensing is assessed by the patent licensing agreements and technology transfer agreements with academic partners. The joint research, adopted from Ybarra and Turk (2009), is assessed by jointly undertaking of research projects with shared resources and working together on new technology or products. The contract research is assessed by research commissioned by industry and undertaken by academic partners to conduct R&D projects or provide R&D services. Consulting includes the consultancy for R&D and business operation. Training is assessed by business training and student training. Researcher mobility is modified from Bekkers and Bodas Freitas (2008) by assessing the flow of university staff members to industry positions and temporary staff exchange programmes. Relation-based transfer includes informal personal contacts, meetings and conferences, and co-authoring. Informal personal contact is assessed by face-to-face visit or phone calls, letters, and e-mail contact between researchers or faculties. Meetings and conferences are assessed by regular group meetings, and the participation in conferences, exhibitions, and workshops. Co-authoring is assessed by the co-authoring a paper with university researchers. The contract-based transfer and relation-based transfer is given an index on a 5-point Likert scale ranging from 1=never to 5=very frequently. The measures of university-industry knowledge transfer mechanisms are shown in **Table 5.1**.

Table 5.1 Measures of University and Industry Knowledge Transfer Mechanisms

Indicator	Item
Equity-Based Transfer	Is the academic partner engaged in equity investment with your company (e.g. Setting up joint-venture spin-off company with the academic partner)? (Yes=1, No=0)
Contract-Based Transfer	***Licensing*** 1. "Patent" licensing or transfer agreements with university. 2. "Technology" licensing or transfer agreements with university. ***Joint Research*** 1. Jointly undertake contract research projects by working together. 2. Jointly undertake contract research projects with shared resources and facilities (e.g. laboratories, equipment, research centres). ***Contract Research*** 1. Contract R&D projects commissioned by industry and undertaken by academics. 2. Contract projects for university service by using the university facilities (e.g. quality detention and clinical trials). ***Consulting*** 1. Hiring university researchers as consultants for R&D research. 2. Hiring university researchers as consultants for business and management. ***Researcher Mobility*** 1. Hires university researchers to be the cooperate researchers. 2. The staff exchange between cooperate and university (e.g. staff mobility programmes). ***Training*** 1. Commissioned academics to training the company employees. 2. Cooperative education for students (e.g. students working as trainees)
Relation-Based Transfer	***Informal Personal Contacts*** 1. Exchanging knowledge with mutual face-to-face visits (e.g. visiting, having dinner, lunch, or coffee together) 2. Exchanging knowledge with informal contacts (e.g. via phone or email) ***Meetings and conferences*** 1. Exchanging knowledge with conferences or workshops to exchange knowledge. 2. Exchanging knowledge with regular group meetings. ***Co-authoring*** 1. Co-author a paper with university researchers

5.2.2 Resource Factors

Resources are classified into five segments, namely, property-based resources, knowledge resources, organisational resources, relationship resources, and TTO resources. Except TTO resources, respondents are requested to indicate the resources profile of the focal firm and the academic partner respectively. Each indicator is given an index on a 5-point Likert scale ranging from 1=never, 2=little, 3=somewhat, 4=much, 5=a great deal. The construction of the resource variables is shown in **Table 5.2**.

Property-based resources are measured by the provision of the R&D investment, including R&D facilities and R&D research funding. Knowledge Resources are developed with 6 items to measure the basic science knowledge to discover new technology, applied science knowledge to practically unitise scientific knowledge (such as patent development or the commercialisation of technological inventions) and the quantity and quality of research manpower. Organisational resources refer to the experience, policies and systems created by the organisation over time.

Table 5.2 Measures of Resource Variables

Indicator	Scale Item
Property-Based Resources	1. Provision of facilities for R&D research (e.g. laboratories, equipments, research centre). 2. Provision of funding for R&D research.
Knowledge Resources	1. Prestigious reputation of the science knowledge level in the field. 2. Good record of scientific publications (including journals, books, reports. .etc). 3. Good record of patents or 'know-how' licensing. 4. Knowledge of the commercialisation of R&D (e.g. developing patents, licenses, and new products). 5. Having a large research team. 6. Having an excellent research team (e.g. experience, credibility).
Relationship Resources	1. Network of scientists members. 2. Network of scientists industry members. 3. Attach great importance to cooperating. 4. Willing to continue to cooperate. 5. Making an effort to resolve the problems of cooperating. 6. Will not abuse the resources of the cooperation.
Organisational Resources	1. Organisational support for university-industry collaboration. 2. A good reward system for university-industry knowledge transfer. 3. Experience of university-Industry collaboration. 4. Experience of transferring patents or licenses.
TTO Resources	1. Sufficient TTO staffs to deal with industry-university cooperation. 2. Sufficient skills of TTO staffs to deal industry-university cooperation. (e.g. Negotiation, patent application, and marketing, IP activities).

Organisational resources are assessed by the university-industry collaboration experience, organisational support and reward for university-industry collaboration. Relationship resources refer to the social resources to facilitate the university-industry interactions. Relationship resources are accessed by the social network of scientist's members and industry members, the commitment to university-industry collaboration, and trust which related to opportunism manners. TTO resources are assessed by the quantity and quality of the university TTO faculties.

5.2.3 Resource Dependency and Resource Complementarity

Resource dependency refers to the extent to which an organisation relies upon its partner for resources (Cummings and Worley, 2008). The measure of resource dependency is adapted from Chen and Chen (2003). Resource dependency is estimated by the value of subtracting the resources possessed by the respondent firm from those possessed by its partner, with the scale ranging from -4 to 4. A larger number means a higher level of dependency of firms on university in collaboration. For example, if the score of a firm's property-based resources was 1, and the score of the academic partner's property-based resources was 5, then the measure of resource dependency on property-based resources would be 4. The higher value implies that the firm is more dependent on the property-based resources of its academic partner. Each type of resource is measured in this way to estimate the firm's resource dependency on its academic partner.

Resource complementarity refer to a symmetric partnership in which each organisation can provide the resources the other partner lacks. The measure of resource complementarity is adapted from Chen and Chen (2003). Resource complementarity are calculated by taking the greatest difference between the resource dependency scores (from –4 to 4) in any two of the four segments. The measure of resource complementarity always lies between 0 and 8, when taking the absolute value. A larger number represents a higher level of resource complementarity in university-industry collaboration. For example, if the score of a firm's resource dependency on its partner for the four resource segments is 4, –2, 1, -3 respectively, this means that the firm brings a little of the first resources and a lot of the last resources to the collaboration compared to its partner. Thus, the value of the resource complementarity would be 7, which is the difference between –4 and 3. A larger number of values imply a higher level of resource complementarity in the university-industry collaboration.

5.2.4 Transaction Cost Factors

Asset specificity refers to the non-redeployable transaction-specific assets that are specialised and unique to a particular exchange relationship (Williamson, 1985). A higher asset specificity means a larger investment relationship and larger transaction costs when the firm switches to another partner. This study identifies three dimensions of asset specificity. Dedicated asset specificity is assessed by the investment made in building up the relationship (Lui et al., 2009), physical asset specificity is assessed by the investment of the specialised facilities and specialised R&D projects into the cooperation, and knowledge asset specificity is assessed by the knowledge transferability when switching to another academic partner.

Uncertainty refers to the degree of unpredicted conditions. This study identifies three dimensions of uncertainty, including market uncertainty, technological uncertainty, and behavioural uncertainty. The formers two uncertainty are developed to measure the inability to predict changes in the external environment. The measure of behavioural uncertainty is adopted from Gulbrandsen et al. (2009) to assess the uncertainty of a partner's behaviour and the collaborative performance. The construction of asset specificity and uncertainty is shown in **Table 5.3**, with each indicator being given an index on a 5-point Likert scale, ranging from 1=strongly disagree to 5= strongly agree.

Table 5.3 Measures of Transaction Cost Variables

Indicator	Scale Item
Asset Specificity	***Physical Asset Specificity***
	1. We have invested a lot of money in specialised facilities/ equipment for the cooperation.
	2. We have invested a lot of money in specialised software for the cooperation.
	Knowledge Asset specificity
	1. Knowledge of R&D outputs can be easily transferred or used elsewhere.
	2. It is hard to find another academic partner who is familiar with this technology.
	Dedicated assets specificity
	1. We have spent a lot of time and effort in building up the relationship with this partner.
	2. It will be a big loss for us if this academic partner switches to one of our competitors.
Uncertainty	***Market Uncertainty***
	1. New products or services are always being introduced in this market.
	2. It is hard to predict market trends.
	Technological Uncertainty
	1. Technology in the industry changes frequently.
	2. The collaborative technology is new and innovative.
	Behavioural Uncertainty
	1. The research target of the cooperation is clear.
	2. It is hard to assess the performance of partners

5.2.5 Knowledge Transfer Performance

Different from previous studies which used archival codified innovation outputs, this study adopts a self-reported questionnaire survey to measure knowledge transfer performance perceived by the respondents. We directly ask the respondents to assess whether or not the knowledge transfer performance has been greatly enhanced through university-industry collaboration. The self-report approach has three advantages, the first of which is that codified indicators are unable to access the quality and potential commercial value of innovation outputs. Secondly, the increase in codified outputs may not all be attributed to university-industry collaboration, and the self-report approach enables the survey to focus on the performance improvement after the formation of the university-industry collaboration (Jiang and Li, 2009). Thirdly, it allows respondents to include informal contacts of technology transfer (Azagra-Caro et al., 2006). Therefore, this subjective approach is useful to provide more accurate and reliable data (Beneito, 2006; Jiang and Li, 2009). The construction of the performance variables is shown in **Table 5.4**, with each indicator being given an index on a 5-point Likert scale ranging from 1=very unsatisfied to 5=extremely satisfied.

Table 5.4 Measures of Knowledge Transfer Performance

Indicator	Scale Item
Knowledge Acquisition	1. Accessing advanced knowledge of technology through academic partner.
	2. Acquiring knowledge to develop a more efficient process to produce products.
	3. Acquiring knowledge to overcome the bottleneck of existing technology.
	4. Enhancing the knowledge of company researchers.
	5. Accessing patent texts in the university unit.
	6. Successfully acquiring university-held patents and know-how' licenses.
Knowledge Creation	1. Developing 'breakthrough' technologies or materials.
	2. Developing "critical" technologies or materials.
	3. Getting more technology award.
	4. Increasing the number of firm's patents
	5. Increasing the value of firm's patents
Commercial Success	1. Increasing the number of new products
	2.Increasing the speed of introducing new products
	3. Increasing the value of the products.

The knowledge transfer performance consists of knowledge acquisition, knowledge creation, and commercial success to assess the innovation outputs of university-industry knowledge transfer. Knowledge acquisition is accessed by the technology knowledge and patent knowledge acquired from the university.

Knowledge creation is assessed by the performance to deliver new knowledge, new technology, and patents generated from a university-industry knowledge transfer. Commercial success is assessed by the commercial performance of technology development and product development.

5.3 Data Analysis

The data collected from the questionnaires is analysed by SPSS, and the data analysis is conducted in two steps. In the first step, a correlation analysis, factor analysis, and reliability analysis are used to purify the measurement scales and identify their dimensionality (Churchill, 1979; Nunnally, 1988). In the second step, regression, multiple regression, and probit regression are employed to test the hypotheses.

Chapter 6 Results

6.1 Sample Profile

The profiles of the firms in this sample are focused on the following descriptive statistics. It can be seen from **Table 6.1**, that 77.3% of the 145 biotechnology firms in the sample are SMEs, which are defined as being enterprises with fewer than 100 employees by Taiwanese standards.

Table 6.1 Firm Characteristics

Characteristics	n	%	Characteristics	n	%
Employees			***Primary Academic Partner***		
Fewer than or equal to 10	32	22.1%	Medical university	28	19.3%
(Micro Enterprises)			National university	40	27.6%
11-50 (Small Enterprises)	61	42.1%	Private university	23	15.9%
51-100 (Medium-Sized Enterprises)	19	13.1%			
101-250 (Medium-Sized Enterprises)	27	18.6%	Industrial Technology Research Institute	14	9.7%
>250 (Large Enterprises)	6	4.1%	Academia Sinica	7	4.8%
	145	100%	Animal Technology Institute Taiwan	6	4.1%
Capital Scale			Other Research Centres	27	18.6%
<NT 4 Million[a]	51	35.2%		145	100%
NT 4 – 8 Million	32	22.1%			
NT 8 Million-2 Billion	34	23.4%	***Collaborative Activities***		
NT 2 -5 Billion	17	11.7%	Joint Research	93	64.1%
>5 Billion	11	7.6%	Contract Research	110	75.9%
	145	100.00%	Consultancy	60	41.4%
Age			Training	38	26.2%
Less than 5 years	51	35.2%	Researcher Mobility	35	24.1%
5-10 years	30	20.7%	Informal Personal Contacts	81	55.9%
10-15 years	11	7.6%	Meetings and conferences	114	78.6%
15-20 years	35	24.1%	Joint Publications	16	11.0%
>20 years	18	12.4%			
	145	100.00%			
Industry Category			***Collaboration with Equity Arrangement***		
Pharmaceuticals and Medicine	40	27.6%	Yes	26	17.9%
Food Biotech	22	15.2%	No	109	82.81%
Agriculture Biotech	17	11.7%		145	100.00%
Medical equipment	16	11.0%			
Biotechnology Services	16	11.0%			
Diagnosis	11	7.6%			
Biological cosmetics	8	5.5%			
Specialty biochemical	5	3.4%			
Environmental Biotech	3	2.1%			
Other	7	4.8%			
	145	100.00%			

[a]: <0.8 Million Pounds, [b]:0.8-1.6 Million Pounds, [c]:1.6-4 Million Pounds, [d]:4-10 Million Pounds, [e]:>

In contrast, according to the definition of the EU for enterprises with fewer than 250 employees (Eurpean Comminsison, 2009), 95.9% of the respondents are SMEs, and this includes micro-enterprises with fewer than 10 employees (22.1%), small enterprises with 11-50 employees (42.1%) and medium-sized enterprises with 101-250 employees (31.7%). The results of the survey show that more than half of the participating firms (55.9%) are less than 10 years old. In addition, they were asked which types of academic institutions were the most important partners for them. More than 60% of the respondents indicated that universities were their primary academic partners, including medical universities (19.3%), national universities (27.6%) and private universities (15.9%). About 40% of the respondents indicated that national research institutions or others were their primary academic partners, such as the *Industrial Technology Research Institute* (9.7%), *Academia Sinica* (4.8%), *Animal Technology Institute* (4.1%), and other research centres (18.6%). When collaborating with their primary academic partner, three quarters of the respondents indicated that their university-industry knowledge transfer was involved with contract research (75.9.2%) and meetings and conferences (78.6%). About half of the respondents indicated that their university-industry knowledge transfer involved joint research (64.1%) and informal personal contacts (55.9%), and consultation (41.4%). About one quarter of the respondents said that they interacted for licensing purposes (26.9%), training (26.2%) and researcher mobility (24.1%). Only 11.0% of the respondents have a joint publication with their primary academic partner. Moreover, 17.9% of the respondents have some experience of collaborating with academic institutions with equity arrangements.

6.2. Factor Analysis and Reliability Analysis

A factor analysis was applied to reveal the underlying pattern of the variables. A KMO Test (Kaiser-Meyer-Olkin Test) and Bartlett's Test of Sphericity were also utilised to examine the sampling adequacy of the factor analysis. The variables measured with one item or two items came from the application of a factor analysis, such as equity-based transfer, resource complementarity, and property-based resources. **Table 6.2** presents the results of the KMO, Bartlett's Test, factor loading, eigenvalues, and the cumulative variance is explained by a varimax-rotated principal component analysis. The KMO examines the partial correlation among the variables, and it needs to be greater than 0.5 for a satisfactory factor analysis to proceed (Kaiser, 1974). The key variables, including contract-based transfer, relation-based transfer,

Table 6.2 Results of Principal Component Analysis

Items	Factor 1	Factor 2	Factor 3	Eigenvalues	Variance Extracted	KMO	Bartlett's χ^2
Contract-based Transfer				2.698	57.56%	0.858	796.023***
Licensing 1	**.621**	.431		1.507			
Licensing 2	**.787**	.463					
Joint Research 1	**.833**	.305					
Joint Research 2	**.799**	.447					
Contract Research 1	**.818**	.405					
Contract Research 2	**.761**	.443					
Consulting 1	.605	**.629**					
Consulting 2	.318	**.700**					
Researcher Mobility 1	.413	**.781**					
Researcher Mobility 2	.498	**.809**					
Training 1	.317	**.774**					
Training 2	.436	**.618**					
Relation-based Transfer				3.318	66.35%	0.812	312.825***
Personal Contacts 1	.840						
Personal Contacts 2	.815						
Meetings & conferences 1	.833						
Meetings & conferences 2	.830						
Co-authoring	.752						
University's Knowledge Resources				3.333	55.51%	0.765	359.375***
Knowledge 1	.681						
Knowledge 2	.702						
Knowledge 3	.804						
Knowledge 4	.814						
Knowledge 5	.770						
Knowledge 6	.690						
University's Relationship Resources				3.921	65.35%	0.853	540.640***
Relationship 1	.755						
Relationship 2	.701						
Relationship 3	.866						
Relationship 4	.897						
Relationship 5	.866						
Relationship 6	.842						
University's Organisational Resources				2.547	63.68%	0.731	199.175***
Organisational 1	.833						
Organisational 2	.839						
Organisational 3	.817						
Organisational 4	.694						
TTO Resources				2.848	71.21%	0.723	317.092***
TTO1	.849						
TTO2	.818						
Firm's Knowledge Resources				3.374	56.63%	0.749	349.377***
Knowledge 1	.701						
Knowledge 2	.697						
Knowledge 3	.836						
Knowledge 4	.776						
Knowledge 5	.789						
Knowledge 6	.688						
Firm's Relationship Resources				1.797	78.56%	0.783	482.005***
Relationship 1	.634						
Relationship 2	.692						
Relationship 3	.805						
Relationship 4	.839						
Relationship 5	.865						
Relationship 6	.795						
Firm's Organisational Resources				2.487	62.18%	0.741	181.959***
Organisational 1	.847						
Organisational 2	.824						
Organisational 3	.786						
Organisational 4	.688						

Note: ***=$p < 0.001$

Table 6.2 Results of Principal Component Analysis *(Continued)*

Items	Factor 1	Factor 2	Factor 3	Eigenvalues	Variance Extracted	KMO	Bartlett's χ^2
Knowledge Resource Dependency				1.684	65.38%	0.723	276.409***
Knowledge 1	**.641**	.149					
Knowledge 2	**.672**	.217					
Knowledge 3	**.821**	.177					
Knowledge 4	**.778**	.179					
Knowledge 5	.250	**.865**					
Knowledge 6	.186	**.897**					
Relationship Resource Dependency				1.346	62.51%	0.717	205.141***
Relationship 1	-.099	**.815**					
Relationship 2	.257	**.765**					
Relationship 3	**.807**	-.068					
Relationship 4	**.706**	-.039					
Relationship 5	**.836**	.208					
Relationship 6	**.692**	.218					
Organisational Resource Dependency				2.278	56.94%	0.741	127.635***
Organisational1	.792						
Organisational 2	.755						
Organisational 3	.775						
Organisational4	.693						
Asset specificity				1.117	70.57%	.749	278.36***
Knowledge Asset 1	**.872**	.406	.517				
Knowledge Asset 2	**.906**	.318	.312				
Physical Asset 1	.348	**.908**	.205				
Physical Asset 2	.364	**.916**	.312				
Dedicated Assets 1	.604	.673	**.649**				
Dedicated Assets 2	.396	.240	**.967**				
Uncertainty				1.293	56.69%	0.646	97.23***
Market Uncertainty 1	**.757**	.178					
Market Uncertainty 2	**.595**	.558					
Technological Uncertainty 1	**.688**	.312					
Technological Uncertainty 2	.228	**.818**					
Behavioural Uncertainty 1	.143	**.656**					
Behavioural Uncertainty 2	.039	**.758**					
Knowledge Acquisition				3.718	61.97%	0.821	442.643***
Acquisition 1	.811						
Acquisition 2	.835						
Acquisition 3	.814						
Acquisition 4	.803						
Acquisition 5	.741						
Acquisition 6	.712						
Knowledge Creation				3.801	76.01%	0.817	604.952***
Creation 1	.896						
Creation 2	.816						
Creation 3	.838						
Creation 4	.907						
Creation 5	.899						
Commercial Success				3.711	74.21%	0.837	516.209***
Commercial Success 1	.887						
Commercial Success 2	.878						
Commercial Success 3	.813						

Note: ***=$p < 0.001$

university resources, firm's resources, resource dependency, knowledge acquisition, knowledge creation, and commercial success, demonstrated KMO values greater than 0.7 and a chi-square at significance level ($p<0.001$), which illustrates the appropriateness of a factor analysis for these variables. A Bartlett's Test was used to examine whether the correlation matrix is an identity matrix, and the results showed that all the variables had chi-square values with a significance level ($p<0.05$), which implies that the relationship among the items is strong and appropriate for a factor analysis in this study.

Factor loading is used as the criterion for the exclusion of items if it is less than 0.5. All the factor loadings of the scales in this study ranged between 0.618 and 0.907 and were, therefore, higher than 0.5. This demonstrates that all the scales are well-defined with the items. The explained cumulative variance was measured by the percentage of the variances of the extracted factor of the total variances. The values of the explained cumulative variance of the construct ranged between 55.51% and 78.56%, all of which exceeded the 50% limit point and presented a good explanation of the extracted factors (Fornell and Larcker, 1981;Tabachnick and Fidell, 2007).

The criterion for selecting the number of factors is eigenvalues of 1.00 or more. According to the results of the principal component analysis, contract-based transfer was grouped into two factors, the first of which comprised items related to licensing, joint research, and contract research. Factor 2 comprised items related to consultancy, training, and research mobility. In order to acquire an in-depth insight into contract-based transfer, it was separated into two variables, namely, "research contract-based transfer" (factor 1) and "general contract-based transfer" (factor 2). In addition, knowledge resource dependency was also grouped into two factors. However, in order to maintain consistency with the measurements of university's resources and firm's resources, these were not separated into two factors. In the same vain, relationship resource dependency was one factor.

Table 6.3 illustrates the means, standard deviations, and reliability of the research variables. The variables of university-industry knowledge transfer were assessed by the frequency of knowledge transfer activities given on a 5-point Likert scale.

Table 6.3 Means, Standard Deviations, and Reliability

	Mean	SD	Number of Items	Reliability (alpha)
Contract-based Transfer	**2.545**	**0.74**	**17**	**0.919**
Research Contract-based Transfer	**2.91**	**0.85**	**6**	**0.860**
Licensing	2.50	1.02	2	0.782
Joint Research	3.09	1.01	2	0.753
Contract Research	3.14	.98	2	0.805
General Contract-based Transfer	**2.21**	**.79**	**6**	**0.819**
Consultancy	2.52	1.07	2	0.809
Training	2.07	.92	2	0.712
Researcher Mobility	2.05	.89	2	0.782
Relation-based Transfer	**2.80**	**.88**	**5**	**0.858**
Informal Personal Contacts	2.88	1.02	2	0.815
Meetings and Conferences	3.24	.99	2	0.803
Co-authoring	2.28	1.00	1	-
University's Resources	**3.80**	**.52**	**22**	**0.932**
University's Property-based Resources	3.71	.70	2	0.733
University's Knowledge Resources	3.72	.60	6	0.857
University's Relationship Resources	4.01	.60	6	0.860
University's Organisational Resource	3.88	.67	4	0.806
TTO Resources	**3.62**	**.73**	**4**	**0.863**
Firm's Resources	**3.81**	**.66**	**18**	**0.910**
Firm's Property-based Resources	3.56	.77	2	0.755
Firm's Knowledge Resources	3.31	.71	6	0.841
Firm's Relationship Resources	3.98	.56	6	0.860
Firm's Organisational Resource	3.81	.66	4	0.793
Resource Dependency	**.16**	**.48**	**18**	**0.836**
Property-based Resource Dependency	.15	.96	2	0.732
Knowledge Resource Dependency	.40	.76	6	0.787
Relationship Resource Dependency	.02	.44	6	0.717
Organisational Resource Dependency	.07	.61	4	0.730
Resource Complementarity	**1.15**	**.70**	**1**	**-**
Asset Specificity	**3.34**	**.60**	**6**	**0.764**
Physical Asset Specificity	3.06	.78	2	0.788
Knowledge Asset Specificity	3.38	.84	2	0.798
Dedicated Assets Specificity	3.58	.74	2	0.712
Uncertainty	**3.46**	**.51**	**6**	**0.730**
Market Uncertainty	3.45	.70	2	0.748
Technological Uncertainty	3.40	.73	2	0.710
Behavioural Uncertainty	3.52	.55	2	0.705
Knowledge Transfer Performance	**3.47**	**.64**	**15**	**0.947**
Knowledge Acquisition	3.54	.61	6	0.873
Knowledge Creation	3.28	.78	6	0.920
Commercial Success	3.58	.77	5	0.912

The research contract-based activities and relation-based activities were seen to be more frequent than general contract-based activities. Among the 10 types of specific knowledge transfer activities, the mean of meeting and conferences was the highest, followed by contract research and joint research activities. The means of training and research mobility were much less than the means of other activities. In terms of resource variables, the mean of university's resources was higher than firm's resources in all the segments, including property-based resources, knowledge resources, relationship resources, and organisational resources. Moreover, it can be seen that satisfaction with knowledge acquisition in university-industry collaborations was higher than that with knowledge creation and commercial success. Cronbach's alpha was used to assess the internal consistency of the instruments. The variables measured with one item came from an application of Cronbach's alpha, such as equity-based transfer and resource complementarity. The results of the reliability analysis show that the Cronbach's alpha of the variables ranged between 0.705 and 0.947, which is above the 0.7 threshold recommended by Nunnally (1988).

6.3. Regression Analysis

H1-H6 focus on university-industry knowledge transfer activities, and H7-H13 focus on university-industry knowledge transfer performance. The effects of university's resources, firm's resources, resource dependency, resource complementarity, asset specificity, and uncertainty of university-industry knowledge transfer (H1-H6) were examined first. Three types of university-industry knowledge transfer governance have been developed in this study, namely equity-based, contract-based, and relation-based transfer. In addition, according to the results of the factor analysis, the contract-based was further divided into two sub-groups, namely, research contract-based and general contract-based transfer. Equity-based transfer refers to jointly setting up a business with an equity arrangement, while research contract-based transfer refers to an R&D-orientated collaboration, including licensing, joint research, and contract research. General contract-based transfer refers to a general collaboration with contract agreements, such as consultancy, training, and researcher mobility, and relation-based transfer refers to an informal interaction without a contract, such as informal personal contacts, meetings and conferences, and publications.

Most university-industry knowledge transfer activities were assessed with their frequency and the related hypotheses were tested with a multiple regression analysis.

However, a firm less frequently engaged in an equity-based arrangement, equity-based transfer was thus assessed with a binary variable, taking on 1 if the firm was engaged in equity-based knowelge transfer activities, and 0 otherwise. A logistic regression was used to examine the hypothesis related to equity-based transfer. This model was estimated with maximum likelihood procedures and had the following specification:

$$\operatorname{logit}[P(y_i = 1)] = \ln\left[\frac{p}{1-p}\right] = \beta_o + \beta_1 x_i$$

Where Xi is a vector of the independent variables.

Table 6.4 presents the regression results for predicting equity-based transfer (Model 1), research contract-based transfer (Model 2), general contract-based transfer (Model 3), and relation-based transfer (Model 4). The Hosmer–Lemeshow goodness-of-fit test of Model 1 with a logistic regression analysis was 0.651(p=0.651>0.05). This insignificant Hosmer–Lemeshow index shows that Model 1 fits well because there is no significant difference between the observed and predicted data, and thus, the independent variables can be used to estimate the dependent variables.

Table 6.4 Regression Results Predicting University-Industry Knowledge Transfer

		Model 1 Equity-based Transfer		Model 2 Research Contract-based Transfer		Model 3 General Contract-based Transfer		Model 4 Relation-based Transfer	
		Beta	Sig.	Beta	Sig.	Beta	Sig.	Beta	Sig.
	Constant	-3.250	(.146)	-.805	(.148)	-.802	(.153)	-.690	(.283)
H1	University Resources	-.817	(.305)	**.381***	(.045)	.021	(.918)	**.464***	(.036)
H2	Firm Resources	**1.847***	(.048)	**.627***	(.000)	**.441***	(.003)	**.326***	(.045)
H3	Resources Dependency	.130	(.862)	-.227	(.226)	-.122	(.516)	-.399*	(.038)
H4	Resource Complementarity	.165	(.600)	.023	(.777)	.010	(.899)	.113	(.234)
H5	Asset Specificity	.793	(.104)	.110	(.366)	**.303***	(.015)	**.288***	(.042)
H6	Uncertainty	-.344	(.444)	.181	(.288)	.173	(.231)	-.125	(.252)
	Hosmer and Lemeshow Test								
	Chi-square	3.483							
	HL df	8							
	HL Sig.	.651							
	-2 Log likelihood	138.782							
	Cox & Snell R Square	.061							
	Nagelkerke R Square	.095							
	R			.652		.572		.532	
	R^2			.425		.327		.283	
	Adjusted R^2			.401		.297		.252	
	F-Statistic			17.034***		11.156***		9.094***	
	N			145		145		145	

*** $p<.001$ (2-tailed). ** $p<.01$ (2-tailed). * $p<.05$ (2-tailed). † $p<.01$ (2-tailed).

H1 states that university resources are positively related to university-industry knowledge transfer, and that this relationship holds regardless of knowledge transfer types, i.e. equity-based, contract-based, and relation-based. The results show that university resources mainly impact contract-based and relation-based transfer, which provides partial evidence for H1. H2 states that a firm's resources are positively related to all types of university-industry knowledge transfers. The results obtained in model 1 show that equity-based transfer is positively related to a firm's resources, whereas other variables have no significant relationship with equity-based transfer. In addition, the results in Model 2-4 demonstrate that a firm's resources are also positively related to two types of contract-based transfer and relation-based transfer. Therefore, these findings provide broad support for H2, suggesting that there is a positive relationship between a firm's resources and university-industry knowledge transfer, regardless of the knowledge transfer type.

However, there is no evidence to support the proposal that resource dependency and resource complementarity are positively related to any type of knowledge transfer activities, and thus, H3 and H4 are not supported. It is worth noting that resource dependency is weakly positively related to equity-based transfer, but it is weakly or strongly negatively related to other types of knowledge transfer. Resource dependency is particularly significantly negatively related to relation-based transfer, as will be discussed later in next chaper. H5 and H6 propose that transaction cost factors are related to university-industry knowledge transfer. The findings show that asset specificity is positively related to general contract-based and relation-based transfer, and thus, H5 is partially supported. The results show that uncertainty has no significant relationship with any type of knowledge transfer, and thus, H6 is not supported.

Additionally, Model 5-8 was used to further examine the relationship between university-industry knowledge transfer and different types of university resources, firm's resources, resource dependency, asset specificity, and uncertainty, and the results are shown in **Table 6.5**. H1 examines the relationship between university resources and knowledge transfer. Model 1-4 demonstrates that university resources are positively related to research contract-based and relation-based transfers. The results of Model 5-8 show that a positive relationship is mainly due to university knowledge resources (H1-2 is partially supported). Otherwise, university property-based resources and organisational resources have no significant effect on any type of knowledge transfer activities (H1-1 and H1-4 are not supported).

Table 6.5 Regression Results Predicting University-Industry Knowledge Transfer

		Model 5 Equity-based Transfer		Model 6 Research Contract-based Transfer		Model 7 General Contract-based Transfer		Model 8 Relation-based Transfer	
		Beta	Sig.	Beta	Sig.	Beta	Sig.	Beta	Sig.
	Constant	-4.551	.065	-.774	.206	-.690	.252	-.477	.482
University's Resources									
H1-1	Property-based Resources	.084	(.835)	.004	(.969)	-.079	(.400)	-.135	(.200)
H1-2	Knowledge Resources	-.565	(.375)	**.293***	(.035)	.097	(.506)	**.495***	(.003)
H1-3	Relationship Resources	**1.945***	(.022)	-.118	(.531)	-.091	(.625)	-.310	(.141)
H1-4	Organisational Resources	-.501	(.479)	.143	(.108)	-.127	(.430)	-.092	(.612)
H1-5	TTO Resources	**1.132***	(.048)	**.186**†	(.092)	.090	(.421)	-.053	(.674)
Firm's Resources									
H2-1	Property-based Resources	.263	(.510)	.008	(.940)	**-.213***	(.047)	-.036	(.750)
H2-2	Knowledge Resources	**1.345***	(.037)	**.274**†	(.069)	**.178**†	(.093)	**.306***	(.050)
H2-3	Relationship Resources	**1.232***	(.041)	.157	(.444)	.062	(.759)	**.392***	(.038)
H2-4	Organisational Resources	**1.869***	(.026)	**.638***	(.000)	**.496***	(.000)	**.337***	(.048)
Resource Dependency									
H3-1	Property-based Resources	**-.683**†	(.067)	**-.213**†	(.069)	-.019	(.803)	-.109	(.212)
H3-2	Knowledge Resources	**1.662***	(.026)	.103	(.410)	.037	(.755)	.171	(.198)
H3-3	Relationship Resources	**-1.043***	(.043)	-.160	(.438)	-.105	(.589)	**-.383***	(.036)
H3-4	Organisational Resources	.408	(.236)	**-.333***	(.020)	**-.311***	(.021)	-.110	(.464)
Resource Complementarity		.471	(.255)	-.032	(.760)	-.048	(.641)	-.061	(.599)
Asset Apecificity									
H5-1	Physical Asset Specificity	.228	(.509)	.023	(.785)	**.321***	(.010)	.004	(.964)
H5-2	Knowledge Asset Specificity	-.042	(.905)	**.269***	(.043)	**.217***	(.048)	**.381***	(.039)
H5-3	Dedicated Assets Specificity	.293	(.481)	.010	(.918)	-.052	(.602)	.134	(.233)
Uncertainty									
H6-1	Market Uncertainty	.146	(.731)	**.263***	(.044)	**.247***	(.038)	**.299***	(.049)
H6-2	Technological Uncertainty	-.662	(.082)	.016	(.865)	-.086	(.359)	-.149	(.158)
H6-3	Behavioural Uncertainty	.397	(.416)	-.035	(.760)	.144	(.200)	.067	(.596)
	Hosmer and Lemeshow Test	6.978							
	Chi-square	8							
	HL df	.539							
	HL Sig.	123.668							
	-2 Log likelihood	.154							
	Cox & Snell R Square	.240							
	R			.678		.629		614	
	R Square			.459		.395		379	
	Adjusted R Square			.392		.319		300	
	F-Statistic			6.797^{***}		5.224^{***}		4.852^{***}	
	N			145		145		145	

*** $p < .001$ (2-tailed). ** $p < .01$ (2-tailed). * $p < .05$ (2-tailed). † $p < .1$ (2-tailed).

Moreover, it is found that university relationship resources and TTO resources are related to equity-based transfer, but they are not related to contract-based or relation-based transfer. It is worth noting that, in Model 5, university's relationship resources and university's TTO resources has a positive effect on equity-based transfer (H1-3 is partially supported; H1-5 is partially supported), whereas has a negative effect on equity-based transfer.

H2 states that there is positive relationship between a firm's resources and knowledge transfer. Model 1-4 demonstrates that a firm's resources are positively related to all types of knowledge transfer activities. The results in Model 5-8 show that a positive relationship is mainly related to a firm's knowledge resources and organisational resources (H2-2 and H2-4 are supported). It is worth noting that a firm's property-based resources show a negative effect on all types of knowledge transfer (H2-1 is not supported), and this negative effect is particularly significant in terms of general contract-based transfer. In addition, it is found that the effects of a firm's relationship resources are varied among different types of knowledge transfer. A firm's relationship resources have a positive effect on equity-based and relation-based transfer (H2-3 is partially supported).

H3 predicts a positive relationship between resource dependency on university and knowledge transfer. The results of Model 1-4 show that overall resource dependency is not related to the four types of knowledge transfer. Model 5-8 indicates that only knowledge resource dependency on university generates a positive effect on knowledge transfer, and the positive effect is particularly significant in terms of equity-based transfer (H3-2 is partially supported). On the other hand, other types of resource dependency have a negative effect on knowledge transfer. For example, property-based resource dependency on university is mostly negatively related to equity-based transfer (H3-1 is not supported), and relationship resource dependency is negatively related to both equity-based and relation-based transfer (H3-3 is not supported), and organisational resource dependency is negatively related to two forms of contract-based transfer (H3-4 is partially supported). In terms of H4 in Model 5-8, there is still no evidence to support the relationship between resource complementarity and knowledge transfer, which is consistent with the result that H4 is not supported in Model 1-4.

H5 focuses on the relationship between asset specificity and knowledge transfer.

Model 1-4 demonstrates that asset specificity is positively related to general contract-based and relation-based transfer. It is found in Model 5-8 that a positive effect mainly comes from physical asset specificity and knowledge asset specificity: physical asset specificity leads to more general contact-based transfer activities (H5-1 is partially supported), and knowledge asset specificity, and knowledge asset specificity widely facilitates two forms of contract-based transfer, and relation-based transfer (H5-2 is partially supported). Otherwise, there is no evidence of a relationship between dedicated assets specificity and any type of knowledge transfer (H5-3 is not supported).

H6 examines the relationship between uncertainty and knowledge transfer. The results of Model 1-4 show that overall uncertainly has no significant relationship with knowledge transfer. It can be found in Model 5-8 that market uncertainty is significantly positively related to the two forms of contract-based transfer and relation-based transfer (H6-1 is partially supported), whereas both technological uncertainty and behavioural uncertainty has no significant impact on knowledge transfer (H6-2 and H6-3 are not supported).

H7-H13 focus on factors related to university-industry knowledge transfer performance, which include university-industry knowledge transfer civilities, university resources, firm resources, resource dependency, and resource complementarity. **Table 6.6** presents the regression results of testing H7-13. Model 9-12 presents the prediction of knowledge acquisition (Model 9), knowledge creation (Model 10), and commercial success (Model 11).

Table 6.6 Regression Results Predicting Knowledge Transfer Performance

		Model 9 Knowledge Acquisition		Model 10 Knowledge Creation		Model 11 Commercial Success	
		Beta	Sig.	Beta	Sig.	Beta	Sig.
	Constant	-1.165	(.247)	-1.026	(.150)	-1.343	(.226)
H7	Knowledge Transfer	**.205***	(.046)	**.197***	(.028)	**.213***	(.018)
H8	University Resources	**.227***	(.037)	**.370****	(.004)	**.293***	(.022)
H9	Firm Resources	.169†	(.060)	**.177***	(.043)	**.205***	(.102)
H10	Resources Dependency	.189†	(.094)	-.150	(.156)	.130	(.223)
H11	Resource Complementarity	-.097	(.186)	-.154	(.145)	-.141	(.125)
	R	.797		.723		.716	
	R^2	.636		.523		.513	
	Adjusted R^2	.614		.495		.484	
	F-Statistic	29.194***		18.333***		17.602***	
	N	145		145		145	

*** $p < .001$ (2-tailed). ** $p < .01$ (2-tailed). * $p < .05$ (2-tailed). † $p < .1$ (2-tailed).

As revealed in **Table 6.6**, knowledge transfer activities are positively related to knowledge acquisition, knowledge creation, and commercial success, and the results support H7. Additionally, both university resources and firm's resources are positively related to knowledge transfer performance. University resources significantly influence three types of knowledge transfer performance, and thus, the data supports H8. Firm's resources has a positive and significant effect on knowledge creation and commercial success ($p < .05$), but it only has a weakly positive effect on knowledge acquisition ($p < .01$). Therefore, the results provide partial empirical support for H9. However, in model 9-11, resource dependency, and resource complementarity have no significant effect on knowledge transfer performance in three models, indicating that these three factors may not be causally associated with knowledge transfer performance. Thus, H10, H11, and H13 are not supported.

Model 12-14 was further used to examine the full relationship between knowledge transfer performance and different types of knowledge transfer, university resources, firm's resources, and resource dependency. **Table 6.7** presents the results of the prediction of knowledge acquisition (Model 12), knowledge creation (Model 13), and commercial success (Model 14).

The results of Model 9-11 indicate that university-industry knowledge transfer is positively related to firm's knowledge transfer performance, including knowledge acquisition, knowledge creation, and commercial success. According to the results of Model 12-14, different types of knowledge transfer have a different effect on firm's knowledge transfer performance. Equity-based and research contract-based transfer are negatively related to knowledge transfer performance (H7-1a is not supported), however, the negative effect of equity-based transfer on three types of knowledge transfer performance are not significant (H7-1b is not supported).

H7-2 predicts hat there is a positive relationship between contact-based transfer and knowledge transfer performance. The data shows that general contract-based transfer is positively related to three types of performance variables, but research contract-based transfer only positively related to knowledge acquisition (H7-2 is partially supported). In addition, the regression results demonstrate that relation-based transfer is positively predictive of knowledge acquisition, knowledge creation, and commercial success (H7-3 is supported).

Table 6.7 Regression Results Predicting Knowledge Transfer Performance

		Model 12 Knowledge Acquisition		Model 13 Knowledge Creation		Model 14 Commercial Success	
		Beta	Sig.	Beta	Sig.	Beta	Sig.
	Constant	-1.016	(.746)	-1.097	(.146)	-.341	(.245)
	Knowledge Transfer						
H7-1	Equity-based Transfer	-.189†	(.061)	-.099	(.114)	-.055	(.402)
H7-2	Contract-based Transfer						
	Research Contract-based Transfer	**.269***	(.337)	.140	(.150)	.045	(.010)
	General Contract-based Transfer	**.215***	(.036)	**.276***	(.005)	**.202***	(.050)
H7-3	Relation-based Transfer	**.210***	(.034)	**.270***	(.004)	**.219***	(.023)
	University Resources						
H8-1	Property-based Resources	**-.247***	(.019)	**-.178***	(.050)	**-.183***	(.046)
H8-2	Knowledge Resources	**.153***	(.048)	**.191***	(.036)	.119	(.216)
H8-3	Relationship Resources	**.229***	(.039)	**.188***	(.050)	**.255***	(.050)
H8-4	Organisational Resources	**.157***	(.047)	**.193***	(.048)	-.040	(.757)
H8-5	TTO Resources	**.188***	(.042)	**.203***	(.025)	**.169***	(.047)
	Firm Resources						
H9-1	Property-based Resources	.011	(.792)	.134	(.056)	.006	(.936)
H9-2	Knowledge Resources	**.175***	(.043)	**.195***	(.026)	.001	(.989)
H9-3	Relationship Resources	**.185***	(.044)	**.189***	(.025)	**.241***	(.033)
H9-4	Organisational Resources	.143	(.056)	.052	(.657)	**.273***	(.027)
	Resource Dependency						
H10-1	Property-based Resources	**-.228***	(.019)	-.112	(.139)	-.015	(.848)
H10-2	Knowledge Resources	.092	(.283)	.038	(.680)	.094	(.050)
H10-3	Relationship Resources	.058	(.505)	.032	(.729)	.081	(.416)
H10-4	Organisational Resources	.128	(.145)	.074	(.430)	-.007	(.942)
H11	***Resource Complementarity***	**-.156***	**(.036)**	**-.172***	**(.025)**	**-.072**	**(.358)**
	R	.842		.857		.815	
	R Square	.710		.735		.664	
	Adjusted R Square	.657		.690		.640	
	F-Statistic	13.513***		9.642***		7.930***	
	N	145		145		145	

*** $p<.001$ (2-tailed). ** $p<.01$ (2-tailed). * $p<.05$ (2-tailed). † $p<.10$ (2-tailed).

H8 and H9 focus on the impact of university resources and firm's resources on knowledge transfer performance respectively. Model 9-11 indicates that a higher level of university resources and firm's resources of university-industry collaboration generate a higher performance of firm's knowledge innovation. Model 12-14 shows the details of the effect of different types of resources. It is found university property-based resources are negatively related to three types of knowledge transfer performance (H8-1 is supported), however, the postive effect of firm's property-based resources on the performance varialbes is not significant (H9-1 is not supported). The influence of knowledge resources is not high as expected. Both university knowledge resources and firm's knowledge resources are positively related to knowledge aguisition and knowledge creation, but no related to commercial succuss (H8-1 and H9-1 are partially supported). In addition, among types of resources, it is found that relationship resources have the strongest and widest influence on knowledge transfer performance. Both university relationship resources and firm's relationship resources demonstrate a significant and positive effect on three performance variables (H8-3 and H9-3 are supported). It is also found that university organisational resources and firm's organisational resources have different effects on firm's knowledge transfer performance. While university organisational resources is positively related to knowledge acquisition and knowledge creation, firm's organisational resources is positively related to commercial success (H8-4 and H9-4 are partially supported). Moreover, the results show that university TTO resources is a positive prediction of knowledge acquisition, knowledge creation, and commercial success (H8-5 is supported).

The results of Model 9-11 show that there is no significant relationship between overall resource dependency and three dimensions of knowledge transfer performance. The results of Model 12-14 also show that the influence of four types of resource dependency is not significant in most of the models. Knowledge resource dependency, relationship resource dependency and organisational resource dependency have no significant effect in three models (H10-2, H10-3 and H10-4 is not supported), whereas property-based resource dependency is negatively related to three dimensions of knowledge transfer performance (H10-1 is not supported in positive effect). Additionally, Model 9-11 shows that there is no significantly relationship between resource complementarity and knowledge transfer performance. It is found in Model 12-14 that resource complementarity can even lead to a worse performance in knowledge acquisition and knowledge generation, which is the opposite of the statement of H11. Thus, these results still provide no evidence to support H11. The **Table 6.8** illustrates the summary of empirical results in this thesis. H2, H2-2, H2-4, H6-1 are supported by combining the results on four types of university-industry knowledge transfer mechanism. H7, H7-3, H8, H8-1, H8-3, H8-5, H9, and H9-3 are supported by combining the results on knowledge acquisition, knowledge transfer and commercial success.

Table 6.8 Summary of Empirical Results

	University-Industry Knowledge Transfer		Knowledge Transfer Performance	
Knowledge Transfer		--	**H7 +**	**Support**
Equity-based Transfer		--	H7-1a +	Not Support
			H7-1b (-)	Not Support
Contract–based Transfer		--	H7-2 +	Partial Support
Relation-based Transfer		--	H7-3 +	Support
University Resources	**H1 +**	**Partial Support**	**H8 +**	**Support**
Property-based Resources	H1-1 +	Not Support	H8-1 (-)	Support
Knowledge Resources	H1-2 +	Partial Support	H8-2 +	Partial Support
Relationship Resources	H1-3 +	Partial Support	H8-3 +	Support
Organisational Resources	H1-4 +	Not Support	H8-4 +	Partial Support
TTO Resources	H1-5 +	Partial Support	H8-5 +	Support
Firm Resources	**H2 +**	**Support**	**H9 +**	**Support**
Property-based Resources	H2-1 +	Not support	H9-1 +	Not Support
Knowledge Resources	H2-2 +	Support	H9-2 +	Partial Support
Relationship Resources	H2-3 +	Partial Support	H9-3 +	Support
Organisational Resources	H2-4 +	Support	H9-4 +	Partial Support
Resource Dependency	**H3 +**	**Not Support**	**H10a +**	**Not support**
			H10b (-)	**Partial support**
Property-based Resources	H3-1 +	Not support	H10-1 +	Not support
Knowledge Resources	H3-2 +	Partial Support	H10-2 +	Not support
Relationship Resources	H3-3 +	Partial Support	H10-3 +	Not support
Organisational Resources	H3-4 +	Not support	H10-4 +	Not support
Resource Complementarity	**H4 +**	**Not support**	**H11 +**	**Not support**
Asset specificity	**H5 +**	**Partial Support**		--
Physical asset specificity	H5-1 +	Partial Support		--
Knowledge asset specificity	H5-2 +	Partial Support		--
Dedicated assets specificity	H5-3 +	Not support		--
Uncertainty	**H6 +**	**Not support**		--
Market uncertainty	H6-1 +	Support		--
Technological uncertainty	H6-2 +	Not support		--
Behavioural uncertainty	H6-3 +	Not support		--

Chapter 7 Discussion and Conclusion

7.1 Conclusion

UIC is an important vehicle for the development of industrial innovation. Although previous studies have made some progress in understanding the motivation and determinants of UIC, they still have limitations. Firstly, earlier studies usually focus on examining the determinants and performance of spin-off and licensing activities, and only a few of them explore other types of university-industry collaborative forms. Secondly, although some studies try to list all the university-industry activities (Arvanitis et al., 2008; D'Este and Patel, 2007; Bekkers and Bodas Freitas, 2008), they only examine the importance and usages of various interactive channels without making a theoretical analysis. Thus, there is still a lack of empirical research to examine the performance of different university-industry knowledge transfer activities. Thirdly, a series of studies which investigate the factors which may operate in a UIC are only explored with a partial glimpse rather than within a comprehensive and theoretical framework. Fourthly, the resources of firms and universities are usually examined independently of each other. Only a few studies have investigated the resource inputs of both parties, and previous research has not examined and compared the resource profiles of firms and universities. Fifthly, most studies examine the university's performance within a UIC, and relatively fewer studies empirically examine the impacts of a UIC on the firm's performance. Sixthly, codified data such as publications, patents and patent citations seem to be the most commonly-used indicators of innovative outputs, having the advantage of providing simple, objective, clear, and available archived data. However, the increasing amount of codified R&D productivity from archived data may be the result of the firm's internal R&D efforts rather than a collaborative achievement.

This thesis seeks to contribute to the literature on UIC by addressing the following questions: Firstly, what is the knowledge characteristic of university-industry interaction activities? Is there a theoretical paradigm to analyse knowledge transfer activities? Do the various knowledge transfer activities contribute differently in the transfer of knowledge from universities to industries? Secondly, are the factors which operate in the UIC able to be analysed in a systematic framework? What are the factors which can more efficiently facilitate a firm's engagement in a university - industry collaboration? What are the factors which enhance the performance of knowledge transfer from university to industry? Finally, are firm-level characteristics more important than university-level characteristics in terms of facilitating a firm to engage in a UIC and enhance knowledge transfer performance? Does the gap between the resources of a firm and a university relate to their engagement in UIC and knowledge transfer performance?

In order to respond to the first question, this study has drawn upon prior work in transaction cost economics and the social exchange theory to distinguish three types of university-industry knowledge transfer mechanisms according to their knowledge and governance characteristics, including equity-based transfer (i.e. spin-off with equity exchange), relation-based transfer (i.e. informal personal contacts, meetings and conferences, co-publishing), and contract-based transfer. It has further divided contract-based transfer into research contract-based transfer (i.e. licensing, joint research, contract research) and general contract-based transfer (i.e. consulting, training, researcher mobility).

In terms of the second question which seeks to systematically explore the factors which operate in a UIC, resource-based theory and transaction cost economics have been used to explore the antecedences of university-industry knowledge transfer. An attempt has been made to examine the role of resource factors and transaction cost factors in terms of university-industry knowledge transfer and knowledge transfer performance. An attempt has also been made to examine the resource profile of firms and universities to examine the effects of resource dependency and resource complementarity. Some evidence is provided of the relationship between antecedences and university-industry knowledge transfer, and its consequences in a bio-technology setting.

In summary, the results of this study indicate that, overall, university-industry knowledge transfer activities improve a firm's knowledge transfer performance. Relation-based transfer and general contract-based transfer are the most effective ways in which to transfer knowledge, and these are followed by research contract-based transfer, and equity-based transfer respectively. In addition, it was found that a firm's overall resources are useful for the formation of a UIC, and a university's overall resources are beneficial for improving the performance of knowledge transfer. A firm's knowledge resources and organisational resources facilitate all types of knowledge transfer, while a university's knowledge resources and organisational resources improve the overall performance of knowledge transfer. The TTO resources and relationship resources of universities and firms facilitate an equity-based transfer and improve the overall knowledge transfer performance. However, greater property-based resources of a university and a firm do not generate more UICs and a better knowledge transfer performance. In fact, a university's greater property-based resources can even decrease the knowledge transfer performance. In addition, it was found that knowledge asset specificity and market uncertainty are related to the formation of a relation-based transfer, general contract-based transfer, and research contract-based transfer. However, resource dependency and resource complementarity do not appear to have an effect on facilitating university-industry knowledge transfer activities and knowledge transfer performance. The findings and implications of the relationship between resource factors, transaction cost factors, resource dependency, resource complementarity, university-industry knowledge transfer, and knowledge transfer performance are discussed in the following section.

7.2 Discussion

7.2.1 Resources and Knowledge Transfer

The results of this study provide evidence that the overall resources of both universities and firms facilitate the engagement of university-industry knowledge transfer activities. The findings are consistent with the resource-based perspective that firms may seek opportunities for an alliance with an external partner to exploit the resources of external providers (Kasch and Dowling, 2008; Gulbrandsen et al., 2009), and universities are also more likely to seek collaboration with firms which have more resources in order to exploit industrial resources. The findings also provide evidence that overall firms' resources have more influence than overall universities' resources on university-industry knowledge transfer activities. Overall firms' resources were found to facilitate all types of knowledge transfer activities, and overall universities' resources were found to mainly contribute to contract-based transfer and relation-based transfer. Furthermore, the empirical results illustrate that not all types of resources contribute to university-industry knowledge transfer activities.

Firstly, it was found that neither universities' nor firms' property-based resources make a significant contribution to facilitate the transfer of university-industry knowledge. Past researchers focused on the relationship between a firm's property-based resources and a university's performance. Industrial grants were found to break a university's limitation of resource deficiency and enable it to conduct more research and utilise human capital. This generates more commercial feasibility and improves a university's performance, including research output, licensing, and the formation of university spin-offs (Landry et al., 2006; De Coster and Butler, 2005; Powers and McDougall, 2005; Leitch and Harrison, 2005; Yusuf, 2008). However, the industry respondents in this study maintained that there is only a slight, not statistically significant, relationship between property-based resources and the transfer of university-industry knowledge. Universities' and firms' property-based resources were shown to be insignificant, and positively related to equity-based transfer and research contract-based transfer, which is consistent with past studies which suggest that research grants are beneficial for universities to conduct more contract research and joint research projects (Bozeman and Gaughan, 2007), and create spin-offs (Wright et al., 2004; Powers and McDougall, 2005; Landry et al., 2006; De Coster and Butler, 2005; Leitch and Harrison, 2005), and licensing (Yusuf, 2008). However, this positive relationship is not as significant as in past studies. On the other hand, both the universities' and firms' property-based resources are even shown to have a slightly negative effect on general contract-based transfer and relation-based transfer. These results show that universities and firms with more research funding or research facilities do not essentially generate more knowledge transfer activities. When researchers have sufficient research budget and facilities, they may put more emphasis on activities which can generate actual research outputs or commercial outputs, and pay less attention to other types of knowledge transfer activities. In addition, since one of the parties has sufficient research funding and research facilities, a tighter relationship with equity-exchange or research contract agreements may be preferred. Because the party with more property-based resources generally has a relatively greater bargaining power in the alliance (Elfenbein and Lerner, 2003; Lerner and Merges, 1998; Kasch and Dowling, 2008), and this power enables the party to determine the allocation of control rights, it is more likely to decide on a higher level of integration and tighter contractual agreements to control knowledge transfer and knowledge exchange activities.

Secondly, the findings of this study indicate that firms' knowledge resources are a major factor in facilitating all types of university-industry knowledge transfer activities, whereas universities' knowledge resources are shown to facilitate the transfer of contract-based and relation-based research. The effect of universities' knowledge resources on university-industry knowledge transfer is not as great as expected, which may be due to the opposite effects suggested by Landry et al. (2006). University researchers with greater publication records may spend time concentrating on advancing academic research knowledge (e.g. research contract-based transfer) and may be less interested in creating spin-offs (e.g. equity-based transfer). The findings of this study suggest that, rather than universities' knowledge, firms' knowledge is the major predictor of university-industry knowledge transfer. Enterprises with considerable knowledge and a high level of technology are usually more aware of their knowledge and ability to innovate, and such firms may not be satisfied with existing technology and will seek for innovation and technological breakthroughs. Firms with strong knowledge have a stronger capacity to search and exploit valuable university partners, and therefore, a UIC boosts their knowledge and technology. In addition, university researchers also like to improve their research productivity and are more willing to collaborate with industry in any form when a firm has a higher level of knowledge base, whereas a firm with less knowledge may focus on existing technology and lack motivation for a UIC or lack the ability to find an appropriate academic partner.

Thirdly, the results of this study reveal that the relationship resources of firms and universities facilitate the formation of equity-based transfer. When universities and firms have higher level of social network, commitment, and trust, they are more likely to engage in equity-based knowledge transfer. These findings support the fact that entrepreneurial networks and trust are key resources for the formation of university incubator activity (McAdam et al., 2006; Grandi and Grimaldi, 2003; Landry et al., 2006; López Iturriaga and Martín Cruz, 2008). In addition, university networks are found to be as important as entrepreneurial networks in university incubator activity. However, the relationship resources of firms and universities have no significant impact on other types of knowledge transfer activities.

Fourthly, firms' organisational resources were found to be an important driver of all types of university-industry knowledge transfer. On the other hand, universities' organisational resources were shown to have no relationship with any type of knowledge transfer activities. Prior studies usually focus on the role of universities' organisational resources and find that these are helpful when forming a UIC (e.g. O'Shea et al., 2005; Azagra-Caro et al., 2006; Lockett and Wright, 2005; Horng and Hsueh, 2005; Siegel et al., 2004; Arvanitis et al., 2008; Wu, 2007). However, this study finds that universities' organisational resources improve an industry-university collaborative performance, but universities' organisational resources do not make a contribution to the formation of industry-university knowledge transfer. This demonstrates that this is the first study to empirically examine firms' organisational resources and universities' organisational resources together. The results illustrate that firms' organisational resources play a different role from that of universities' organisational resources. Firms' organisational resources facilitate the formation of industry-university knowledge transfer, but scarcely improve knowledge transfer performance. Taken together, a firm's experience, support and rewards initiate the formation of industry-university knowledge transfer, and a university's experience, support and rewards improve the quality and efficiency of such a transfer.

Finally, the quantity and quality of universities' TTO staff in terms of negotiation, patent application, marketing, and intellectual property activities is found to be helpful in promoting a university-industry equity-based and research contract-based transfer. However, TTO resources have no effect whatever on the other two types of knowledge transfer. The findings of this research support studies which claim that there is a greater percentage of universities with older TTOs using equity-based intellectual property transactions (Feldman et al., 2002), and experienced TTOs are more willing to engage in equity activities (Bray and Lee, 2000). This is because TTOs help universities and firms to maintain close contact and better identify opportunities to create spin-offs (Lockett and Wright, 2005). Staffing practices in TTOs may explain why some universities are more proficient than others in managing intellectual property (Siegel et al., 2003a, 2003b). Older TTOs and experienced TTOs who have had more practice are more able to deal with university-industry research activities as well as commercial activities. Macho-Stadler et al. (2007) use an economic model to explain the role of TTOs and their results indicate that TTOs may lead to less licensing because they have an incentive to integrate and shelve similar projects which raise the price of licensing. However, this study's empirical findings indicate that TTOs do not decrease licensing activities. Instead, they provide a bridge between universities and industries, and increase licensing, joint research, and contract research.

Relationship resource factors and knowledge transfer mechanisms can be summarised as follows:

- Firms' knowledge resources and organisational resources only demonstrate a stronger effect on four types of knowledge transfer.
- Universities' TTO resources facilitate equity-based transfers and research contract-based transfers.
- The relationship resources of universities and firms particularly promote equity-based transfers.

In addition, research contract-based transfers are more likely to arise when universities and firms have a greater level of knowledge resources and greater TTO resources. Relation-based transfers are more likely to occur if both parties have a greater level of knowledge resources, but fewer TTO resources, and while general contract-based transfers are more related to firms' resources, they have no relationship with the amount of universities' resources.

7.2.2 Resource Dependency, Complementarity and Knowledge Transfer

The regression results reported in chapter 6.3 indicate that resource dependency, the gap between university and industry resources, is more influential on equity-based transfers. An equity-based transfer is more likely to be formed when the university has a great many more knowledge resources than the firm (stronger knowledge resource dependency), and the firm has more property-based resources and relationship resources than the university (less property-based and relationship resource dependency). It is reasonable to suppose that a firm with stronger financial resources and stronger networks, but less knowledge, is more likely to assess and acquire university knowledge with financial advantages and equity arrangements. These results support the importance of knowledge dependency observed by van de Vrande et al. (2009). Larger knowledge dependency leads firms to have a limited capability to absorb universities' knowledge. Problems of information asymmetries make the contract arrestment difficult and complex, and a higher level of integration with equity-exchange is preferable for the firm to acquire the university's knowledge and control the knowledge transfer.

On the other hand, it seems that knowledge dependency has no significant influence on other types of knowledge transfer. Where there is no gap between the university's knowledge and the firm's knowledge, and the firm has many more organisational and property-based resources than the university (less organisational and property-based resource dependency), a research contract-based transfer is more likely. This implies that research contract-based transfers are more likely to occur when both parties have a similar level of knowledge resources, and the firm needs stronger financial support and organisational support to facilitate licensing, joint research, and contract research activities with the university. However, when the firm lacks a stronger property-based resource position but has many more organisational resources (less organisational resource dependency but no property-based resource dependency), a general contract-based transfer is more likely to be chosen, because this may be a less expensive way to acquire knowledge via consulting, researcher mobility, and training. When a firm does not have strong organisational support or strong financial support, it can only utilise its strong relationship resources (less relationship resource dependency) and actively connect to university researchers via personal contacts. Thus, a relation-based transfer occurs.

However, no evidence was found to support the fact that resource complementarity facilitate university-industry knowledge transfer activities, and a possible explanation for this is that resource complementarity may influence university-industry knowledge transfer activities in a complex way which cannot be captured by the gap between different types of resources. For example, a university-industry knowledge transfer may arise from knowledge resource complementarity when the university holds a strong basic science knowledge background and the firm hold a strong applied science knowledge background. However, the measures used in this present study could not assess complementarity within the same types of resources.

7.2.3 Transaction Costs and Knowledge Transfer

The findings indicate that all types of asset specificity and uncertainty have no significant effect on equity-based transfer. Although TCE suggests that asset specificity and uncertainty increase the transaction costs and lead to equity exchange and vertical integration (e.g. Rindfleisch and Heide, 1997; Gulbrandsen et al. 2009; Chen and Chen, 2003; Aulakh and Gencturk, 2008; Poppo and Zenger, 2002), the results of this present study do not provide evidence that this proposition is valid in

UICs. A possible explanation for this is the different setting of the UIC and inter-firm alliance. A greater asset-specific investment in an inter-firm partnership produces a greater risk of opportunistic behaviour. The enterprise partner may share its knowledge and resources, but may also learn critical technology or hire crucial researchers from the focal company and then become a stronger competitor. A university-industry equity-based transfer has a lower risk of knowledge racing between partners, or the risk that the university partner may become an industry competitor. Therefore, there is less of an impact of asset specificity and uncertainty than there would be in an inter-firm condition.

On the other hand, among types of asset specificity and uncertainty, knowledge asset specificity and market uncertainty were found to be significantly related to other types of university-industry knowledge transfer, including research contract-based transfer, general contract-based transfer, and relation-based transfer. If a firm invests more highly-specialised knowledge, or it is hard to find another academic partner who is familiar with this technology, or the R&D outputs can be easily transferred elsewhere, it is more likely to collaborate with a university and transfer knowledge in a contract-based and relation-based form. The results of the present study reveal that market uncertainty has more of an impact than technology uncertainty and behavioural uncertainty on university-industry knowledge transfer. When the market changes quickly and the market trend is unpredictable, a firm is more likely to collaborative with a university.

7.2.4 Knowledge Transfer and Knowledge Transfer performance

The results indicate that more overall university-industry knowledge transfer activities improve a firm's knowledge transfer performance in knowledge acquisition, knowledge creation, and commercial success. In addition, it was found that different types of knowledge transfer activities demonstrate different impacts on knowledge transfer performance. The empirical results show that general contract-based and relation-based transfers are more effective in transferring knowledge, followed by research contract-based transfer, and equity-based transfer respectively.

Relation-based transfer and general contract-based transfer were found to improve the knowledge transfer performance in terms of knowledge acquisition, knowledge creation, and commercial success. Two types of contract-based transfer were shown to have different effects on knowledge transfer performance. General contract-based transfers were found to enhance the performance of knowledge acquisition and knowledge creation, bringing a firm commercial success, whereas research contract-based transfers only improve knowledge acquisition. It is interesting to note that general contract-based transfers (e.g. consulting, researcher mobility, training) are more efficient in transferring knowledge than research contract-based transfers (e.g. licensing, joint research, and contract research). The results of the present study indicate that research contract-based transfers contribute to knowledge acquisition, including the successful acquisition of university-held patents and 'know-how' licenses, access to the university's patent texts and advanced knowledge of technology, and access to knowledge to overcome the bottleneck of existing technology and enhance the knowledge of the company's researchers. However, they contribute little to firms' abilities to develop 'breakthrough' and "critical" technologies, or to increase the number and value of their patents. This implies that research contract-based transfers focus on the development of basic science rather than applied science. In addition, the knowledge acquired through research contract-based transfers may not be internalised as business knowledge. The firm may excessively rely on the university partner to do the research and simply wait for the research results from the university researcher. Therefore, these findings suggest that firms should make more effort to exploit the commercial potential of licensing and research projects, and try harder to become involved in research contract-based knowledge transfer activities. Rather than waiting for the research outputs from the university, the firm should encourage business researchers to absorb and internalise the university's knowledge, thus further improving its own technological capability.

On the other hand, the regression results show that equity-based transfers are significantly negatively related to knowledge acquisition, and insignificantly negatively related to knowledge creation and commercial success. The present study posits that there are two opposing effects of equity-based transfers on knowledge transfer performance. The positive effects involve equity binding, a formal control system, and a mutual commitment to facilitate knowledge transfer (Nakos and Brouthers, 2008, Das and Teng, 2002), and the negative effects relate to inflexibility and the rigidity of equity binding (Okamuro, 2007). The results of the present study show that the negative effect of equity-based transfers is stronger.

These findings point to the proficiency of a flexible mechanism as opposed to a more tightly bundled mechanism in achieving overall knowledge transfer performance. Equity-based and research contract-based transfers usually involve more complex and detailed agreements about collaboration. However, more tightly bound activities do not demonstrate a better knowledge transfer performance. When comparing the two types of contract-based transfer, general contract-based with a less formal contract provides a better knowledge transfer performance than research contract-based transfer. This implies that the flexible mechanism overrides the tighter bundle in acquiring a university's knowledge, and further generates more knowledge and commercial success. These findings are consistent with studies which propose a flexible approach for an alliance. For example, Sherwood and Covin (2008) found that informal communications between technological experts have a stronger influence on a successful acquisition of technological knowledge than knowledge transfer via a formal team. A relation-based form as opposed to a contract-based form is found to be more effective and influential in improving alliance performance in terms of alliance strength, alliance stability, and knowledge transfer between alliance partners (Cavusgil and Lee, 2006). The findings of the present study suggest that formal contacts may provide a basis for the initiation of a partnership, whereas a relation-based form can leverage knowledge transfer performance and alliance performance. Informal self-enforcing agreements have the advantage of trust and reputation, which promotes the resolution of any disagreement in the collaboration, and informal binding often supplants the formal controls of contracts (Dyer and Singh, 1998; Cavusgil and Lee, 2006; Vandaele et al., 2007). Thus, an informal relation-based transfer launched by active contacts is more flexible and efficient to generate a better knowledge trasnfer performance.

7.2.5 Resources and Knowledge Transfer Performance

The empirical results provide evidence that both the overall university's resources and overall firm's resources improve a firm's knowledge transfer performance of knowledge acquisition, knowledge creation, and commercial success. These findings confirm the logic of the resource-based theory, that the tangible resources and intangible resources originated internally and acquired from external partners contribute to a firm's value creation and performance. When examining the effect of different types of resources, it was found that not all resources contribute to knowledge transfer performance.

Firstly, it was found that the property-based resources of both university and firm show no evidence to enhance the firm's knowledge transfer performance. Several previous studies, which focused on the effect of a firm's grants on a university's academic performance, found that industry grants increased the academic output of university researchers (e.g. Blumenthal et al., 1996; Gulbrandsen and Smeby, 2005; Owen-Smith, 2003; Van Looy et al., 2004; Boardman and Ponomariov, 2009). This thesis is the first empirical study to examine whether or not a firm's own property-based resources increase its knowledge transfer performance when collaborating with a university. It suggests that a firm's investment in R&D research and R&D facilities provides motivation and resources for university researchers to devote themselves to research, and it also enables the firm to have more influence and control over knowledge transfer activities. However, the regression results do not provide evidence of this. Without the knowledge base of both university and industry, greater R&D funding and R&D facilities could not be utilised to create more knowledge and commercial success. In addition, it was found that universities' property-based resources have a significantly negative effect on knowledge acquisition, knowledge creation, and commercial success, and these results are consistent with findings that public subsidies impede industry innovation projects (Bougrain and Haudeville, 2002; Okamuro, 2007). A public subsidy may increase the moral hazard problems in university-industry research projects (Okamuro, 2007), since with such a subsidy, firms may be more likely to select risky projects, or projects still in the early stage of development and this, in turn, will lower the possibility of success. In addition, a university with more property-based resources may be more autonomous and less willing to accommodate business requirements and business targets, which will lower the possibility of knowledge acquisition and knowledge creation. Therefore, it is suggested that policy makers increasing the university budget in UIC projects may not be the most efficient way to facilitate knowledge transfer from university to industry. Instead, the public sector should provide a platform to initiate university-industry interaction and supply more public TTO resources, such as specialised consultants with backgrounds of law, science, and business.

Secondly, it was found that the knowledge resources of both universities and firms facilitate knowledge acquisition and knowledge creation, including the gathering of more technological knowledge and patent knowledge from universities and the improvement of firms' technological development and patent development. However, there is no evidence that the knowledge resources of universities and firms generate firms' commercial success in increasing the number, speed, and value of new product development. Previous researchers who focused on the impact of university knowledge found that university knowledge improves universities' commercialisation performance, such as the creation of patents and licenses (Arvanitis et al., 2008; Chang et al., 2006; Owen-Smith and Powell, 2003; Horng and Hsueh, 2005). It was also found that universities' knowledge enhances firms' technological development, patenting, and new product development (Fischer and Varga, 2003; Lööf and Broström, 2008; Baba et al., 2009). However, the results of this study show that, although the knowledge of both universities and firms increase firms' technological capability and innovation capability, these capabilities do not directly generate commercial success. This implies that knowledge inputs alone may not directly produce commercial success. Business processes and commercial success involve complex systems, including supporting organisational mechanisms and the coordination of various business functions.

Thirdly, among the four types of resources, relationship resources were shown to be key for enhancing university-industry partnerships and overall knowledge transfer performance. The relationship resources of both universities and firms significantly improve the performance of knowledge acquisition, knowledge creation, and commercial success. These findings support the social capital perspective, which posits that trust, commitment, and social networks positively affect alliance performance and innovation performance (Kwon, 2008, van Rijnsoever et al., 2008; Tether and Tajar, 2008; West and Noel, 2009; Thune, 2007; Plewa and Quester, 2007; Inkpen and Tsang, 2005). From a managerial perspective, these findings suggest that even though there is less risk of academic partners becoming potential industrial competitor, bilateral trust and commitment are key elements of success in the transfer of university-industry knowledge. Trust decreases transaction and negotiation costs by reducing or eliminating both ex-ante and ex-post opportunism (Zaheer and Venkatraman, 1995), decreases the fear of opportunistic behaviour, and improves openness and transparency, thus smoothing the exchange of knowledge (Doz and Hamel, 1998; Kwon, 2008), leading to a better knowledge transfer performance.

Fourthly, universities' organisational resources and firms' organisational resources were found to play different roles in knowledge transfer. Universities' organisational resources were shown to significantly increase knowledge acquisition and knowledge creation, whereas firms' organisational resources were shown to increase commercial success. Few prior studies have examined the role of organisational resources in UICs, but the findings of this present study demonstrate that organisational support, rewards, and alliance experience are important for university-industry knowledge transfers. A firm's organisational resources enable it to find an appropriate partner and deal with the feedback from that partner in terms of technological transfer activities (Owen-Smith and Powell, 2003), and this enhances the faculty's involvement in the transfer of technology (Horng and Hsueh, 2005). Financial investment and knowledge inputs may not directly lead to business success without well-organised and experienced systems. In addition, the results show that the organisational resources of universities and firms influence different dimensions of knowledge transfer performance. Universities' organisational resources are beneficial for knowledge acquisition and knowledge creation, while firms' organisational resources are helpful for commercial success. This implies that there is an essential gap in the purpose of cooperation between universities and firms. Universities focus on technological invention while firms emphasise commercial potential. In Taiwan, university promotion and tenure decisions are exclusively based on publications and federal research grants, with no weight being placed on patents and industrial partnerships. Therefore, in order to achieve commercial success, firms need to exert more effort and provide more incentives to encourage their academic partners to engage in technological invention with commercial potential rather than pure scientific research.

Finally, TTOs are analysed as university-level resources, which are usually not available at firm level. It was found that a greater quantity and quality of TTO staff enhance firms' performance of knowledge acquisition, knowledge creation, and commercial success. These findings confirm the fact that TTOs are key factors of university-industry knowledge transfer, which are particularly important in the traditionally non-commercial nature of university environments (Lockett and Wright, 2005; Powers and McDougall, 2005; O'Shea et al., 2005, 2007; Macho-Stadler et al., 2007). TTOs not only initiate partnerships between businesses and universities, but also encourage university researchers to disclose their inventions, which increases the effectiveness of university-industry technological transfer and utilises university researchers' basic knowledge (Bailetti and Callahan, 1992; Cyert and Goodman, 1997; Bayona Sáez et al., 2002). In addition, 95.9% of the respondents in this study were SMEs, and the findings show that TTOs are particularly beneficial for SMEs in saving effort, time, and money on intellectual property activities, such as applying and maintaining a patent, which boosts the performance of knowledge transfer.

The relationship between resource factors and knowledge transfer performance can be summarised as follows. Overall universities' resources are more beneficial for knowledge transfer performance than overall firms' resources. University TTOs and the relationship resources of universities and firms are major resource factors to promote the performance of knowledge transfer in all dimensions. The knowledge resources of universities and firms improve knowledge acquisition and knowledge creation, but they do not directly produce commercial success. Universities' organisational resources improve knowledge acquisition and knowledge creation, whereas firms' organisational resources generate commercial success. In addition, the property-based resources of universities and firms make no contribution to knowledge transfer performance, the greater universities' property-based resources even decrease the performance of knowledge transfer.

7.2.6 Resource Dependency, Complementarity and Knowledge Transfer Performance

The regression results show that resource dependency has no significant relationship with knowledge transfer performance, and this insignificance may be the result of a conflict between two opposite effects of dependency. On the one hand, a higher resource dependency on the university will increase knowledge transfer performance, because the firm may tend to consider the interests of the university researcher and be more willing to assist, comply and provide the information the university needs. A higher resource dependency also increases satisfaction with the partner because of the greater perceived contribution of the university. However, a greater resource dependency reduces the firm's autonomy and control over research projects, decreases its interest in making an effort to engage in research activities, and thus, impedes the knowledge transfer performance. These two opposite effects may explain the insignificance in this thesis and the diverse results about the relationship between resource dependency and alliance performance (e.g. Kotter, 1979; Lewis and Lambert, 1985; Escribá and Menguzzato, 1999; Gray, 1985; McDonald and Gieser, 1987; Blankenburg et al., 1999). The effects of the four types of resource dependency on knowledge transfer performance were also examined, and while property-based resource dependency is negatively related to all knowledge transfer performance dimensions, knowledge resource dependency, relationship resource dependency, and organisational resource dependency have no effect whatever on any dimension of knowledge transfer performance. When the university is in a stronger property-based resource position, it may not regard the firm's needs as being a priority, and the firm may lose autonomy and control over the research projects. The findings of this present study suggest that cooperation with a top university with a greater amount of resources does not necessarily generate a better cooperative performance. This is because the firm may lose control of the research development and knowledge transfer activities, and the knowledge resource gap will also make the firm incapable of digesting and utilising the university' knowledge.

Finally, contrary to expectation, greater resource complementarity were shown to lead to worse knowledge transfer performance, particularly in terms of knowledge acquisition and knowledge generation. According to the inter-firms alliance study, the usage of two sets of complementarity resources usually yield a higher total return (Chi, 1994), reducing the risk of mutual exploitation and making the alliance sustainable (Chen and Chen, 2003). The complementarity of skills of the collaborative partner is emphasised as being an important factor of cooperation stability and R&D partnership success (Park and Ungson, 2001; Lhuillery and Pfister, 2009). However, the results of the present study do not provide evidence of the synergistic effects of resources complementarity on knowledge transfer performance. Lhuillery and Pfister (2009) found that R&D collaboration with public research organisations is more likely to end in failure than collaboration with suppliers or customers, because of specific management difficulties and firms' low investment associated with public research organisations. Thus, the different cultures and processes of universities and industries may mean that firms are unable to fully exploit the advantages of complementary resources with universities, and therefore this has no effect on knowledge transfer performance.

7.3 Limitations

This study is subject to certain empirical and methodological limitations, the first of which is that it suffers from a common limitation of researchers who use a single industry study. While single industry studies have the benefit of control over market and environmental idiosyncrasies, this thesis has focused on the biotechnology industry bounded by specificities, which may limit the generalisability of the findings. However, the biotechnology industry is considered to be a suitable context to explore university-industry research collaboration and knowledge transfer, because it is a highly-intensive technological industry, and universities and research institutes are the primary source of basic science research for the biotechnology industry to discover the potential commercial value of academic research (Zucker et al., 1998, Quintana-Garci and Benavides-Velasco, 2004). Thus, it is believed that the findings of this present study can make a valuable contribution to understanding knowledge transfer in UICs.

The second limitation is that, in order to gather information about university partners' resource profiles, this thesis has focused on research collaboration with one major academic partner. We used dummy variable to assess equity-based transfer because the informants in the pre-test presented that they are rarely involved more than one time of spin-off activities with the same academic partner. In addition, the equity-based form is usually measured using a dummy variable to assess whether a firm engages in an equity joint venture alliance (Chen and Chen, 2003), or a corporate spin-off in a specific year (Agarwal et al., 2004; López Iturriaga and Martín Cruz, 2008), or whether university researchers create spin-offs (Landry et al., 2006). Therefore, different from the measures of other knowledge transfer activities which use frequency to assess the level of knowledge transfer, this present study uses a dummy variable to assess equity-based transfer activities. Therefore, a means and reliability analysis of equity-based transfer is unavailable.

The third limitation is that this study has focused on firms' perspective of management or administrative positions which create a university-industry research collaboration. This raises the possibility of differences in perception between personnel at different organisational levels. For example, business executives who are engaged in a UIC may have different opinions than business researchers who actually perform university-industry R&D tasks. Hence, this thesis addresses the fact that it may find different ratings for all firms' staff who perform various knowledge transfer activities and the resource profiles of firms and universities (Bekkers and Bodas Freitas, 2008). In addition, the perceptions of personnel in different organisations may be different. For example, business executives and university academic staff may have different perceptions and interpretations of knowledge transfer activities and the resource profiles of firms and universities. Although this aspect is beyond the scope of this present study, it can raise interesting questions for future research and thinking.

The fourth limitation is a lack of evidence of the positive effects of resource complementarity on university-industry knowledge transfer activities and knowledge transfer performance. One possible explanation for this lack of findings is that resource complementarity were assessed by taking the greatest difference between the resource dependency scores in any two of the four segments. Therefore, it was not possible to examine the effect of resource complementarity in the same types of resource. It is hard to measure resource complementarity in the same type of resource using the quantitative method, and examining the impact of resource complementarity in the same types of resources was not the main purpose of this thesis. A further investigation into the concept and measures of resource complementarity in future studies may provide a deeper insight into their impact.

In addition, this thesis highlight the resource factors which exist in both universities and industries, which implies that other relevant resource variables have been missed, such as firms' manufacturing ability, firms' marketing ability, universities' teaching obligations, and the dynamics of the scientific field (e.g. Landry et al., 2006; Arvanitis et al., 2008; Li and Chen, 2009; van Rijnsoever et al., 2008). Furthermore, research cooperation is a longitudinal process, and this study only provides a cross-sectional survey, with no time dimension to show how knowledge transfer evolves and changes over time. Therefore, it may not be possible to measure the actual knowledge transfer performance when the collaboration is still in the early stage.

7.4 Future Research Directions

Future research is needed to facilitate a more successful knowledge and technology-seeking collaboration between industries and their academic partners, and several areas for additional research are suggested. Firstly, past studies usually used codified knowledge, such as patents or patent citations to measure the transfer of knowledge (e.g. Rothaermel and Thursby, 2005; Hong, 2008; Rosell and Agrawal, 2009). However, codified data is limited in terms of transferring tacit knowledge. In order to capture both codified and non-codified knowledge transfer activities, this thesis uses university-industry interaction and collaborative activities to reflect the transfer of knowledge between universities and industries. Since it is questioned whether or not collaborative activities actually measure knowledge transfer, future research needs to develop an alternative measurement which more efficiently captures the transfer of knowledge.

A second potential area is that future research could extend the framework and results of the analysis in this thesis to other industrial segments and geographical contests to provide an additional explanation for university knowledge of industry innovation. In addition, the research framework of this thesis could be expanded to investigate equity-based, contract-based, and relation-based knowledge transfer in inter-firm contexts. The ten university-industry knowledge transfer activities identified in this thesis, including spin-offs, licensing, joint research, contract research, consultancy, training, research mobility, meetings and conferences, informal contacts, and co-authoring, also take place between firms and firms. The results of inter-firm knowledge transfer may be different from the results of this thesis. For example, inter-firm knowledge transfer carries a higher level of risk and opportunistic behaviour. The transaction cost factor may play a much more important role in this case, and it is likely that an equity-based transfer may be preferred to reduce the risk.

A third area suggested for future research would be to explore other resource variables which are inherent in a university-industry collaboration, and which may facilitate a successful knowledge transfer and firm performance, or even extend the university performance. As already noted, some resource variables are missed in this thesis because they are the attributes of one partner or the other. These include firms' manufacturing ability and marketing ability, and universities' research capacity with teaching obligations. Variables related to knowledge transfer and performance could be measured per university, and this may include the capability with which the parties perform the knowledge transfer (e.g. absorptive capacity, openness), and the characteristics of different types of organisation (e.g. partner's value and culture in the alliance, partner's value and culture in knowledge sharing, partner's value and culture in commercialisation). Additional future research into the determinants of university-industry knowledge transfer could focus on exploring the role of other transaction cost factors (e.g. opportunism, alliance complexity, small numbers bargaining, and information impactedness) in the governance structure and the successful knowledge transfer of collaborative partnerships.

Another suggested area for future research could focus on exploring the role and influence of each type of university-industry knowledge transfer activity. Since a number of studies have focused on investigating the determinants and performance of university-industry spin-off and licensing activities, the contribution and characteristics of other types of knowledge transfer activities could be investigated and discussed.

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Appendix

Appendix 1 Table of Abbreviations

Abbreviations	Full Name
DSME	Department of Small and Medium-sized Enterprises
HEIs	Higher Education Sectors
IP	Intellectual Property
JV	Joint Ventures
M&A	Merge and Acquisition
MEA	Ministry of Economic Affairs
MIT	Massachusetts Institute of Technology
MOE	Ministry of Education
NSC	National Science Council
R&D	Research and Development
RBT	Resource-Based Theory
RET	Relational Exchange Theory
RDT	Resource Dependence Theory
SME	Small and Medium-sized Enterprises
TCE	Transaction Cost Economics
TTO	Technology transfer office
UIC	University - Industry Collaborations
U. S.	United Stated

Appendix 2 Definition of Constructs

Construct	Conceptual Definition	References
University-Industry Knowledge Transfer	Knowledge and technology transfer between academic institutions and the business sector are understood as any activities aimed at transferring knowledge or technology, which may help either the company or the academic institute, to further pursue its activities.	Dosi (1982), Arvanitis (2008)
Equity-Based Transfer	The collaboration and knowledge transfer involves capital contribution such as equity participation and spin-off activities.	Gulati & Singh (1998), Das & Teng (2002)
Contract-Based Transfer	The use of a formalised, legally binding agreements or contracts to govern the collaboration and knowledge transfer and to resolve the opportunistic problem, govern the partnership, and stabilise the relationship.	Macneil (1978), Das & Teng (2002), Cavusgil & Lee (2006)
Relation-Based Transfer	The collaboration and knowledge transfer based on neither equity exchange nor formal contract, but on informal interaction and informal binding to facilitate the partnership.	Zaheer & Venkatraman (1995), Poppo & (2002), Cavusgil & Lee (2006)
Property-Based Resources	Refers to the resources are legal properties owned by firms, such as financial capital and physical resources.	Miller and Shamise (1996) (Yusuf, 2008)
Knowledge Resources	Refers to a firm's intangible know-how and skills, such as basic science knowledge to discover new technology, applied science knowledge to practically unitise scientific knowledge and the research manpower.	Miller and Shamise (1996)
Relationship Resources	The resources that facilitates individual or collective action, generated by networks of relationships, reciprocity, trust, and social norms.	Bourdieu (1974)
Organisational Resources	The intangible resources which enable the organisation to provide a well-organised system to support and facilitate knowledge transfer, such as the experience, policies and systems created by the organisation over time.	This study
TTO Resources	The quality and quality of Technology transfer office staffs.	This study
Resource Dependency	The extent to which an organisation relies upon its partner for resources	Cummings & Worley (2008)
Resource Complementarity	A symmetric partnership in which each organisation can provide the resources the other partner lacks to jointly use two sets of resources to yield a higher total return.	Chi (1994), Chen & Chen (2003)
Asset specificity	A durable investments which are undertaken in support of particular transactions, the opportunity cost of which investments is much lower than best alternative use or by alternative users should the original transaction be prematurely terminated	Williamson (1985, 1986)
Uncertainty	The focal firm's inability to predict a partner's behaviour and changes in the external environment	Joshi & Stump (1999), Williamson (1985)

Appendix 3 Studies and Summarised Tables

Author(s)	Table	Author(s)	Table
Arvanitis et al. (2008)	Table 2.2	Landry & Amarar (1998)	Table 2.9
Baba et al. (2009)	Table 2.2	Lee & Cavusgil (2008)	Table 2.9
Bekkers & Bodas Freitas (2008)	Table 2.13	Lee & Win (2004)	Table 2.13
Bercovitz & Feldman (2007)	Table 2.2	Leitch & Harrison (2005)	Table 2.4
Boardman (2008)	Table 2.12	Lin et al. (2009)	Table 2.10
Buvik & Haugland (2005)	Table 2.10	Lui et al. (2008)	Table 2.9
Chang et al. (2006)	Table 2.2	Mora-Valentin et al. (2004)	Table 2.10
Chen & Chang (2004)	Table 2.10	Nakos & Brouthers (2008)	Table 2.12
Chen & Chen (2003)	Table 2.4	Østergaard (2008)	Table 2.2
Claro, Hagelaar1, and Omta (2003)	Table 2.12	Owen-Smith & Powell (2003)	Table 2.2
Colombo et al. (2008)	Table 2.10	Philbin (2008)	Table 2.12
D'este and Patel (2007)	Table 2.13	Polt, Rammer, and Schartinger (2001)	Table 2.13
Fischer & Varga (2003)	Table 2.2	Rijnsoever & Castaldi (2008)	Table 2.2
Garc´ıa-Canal et al. (2008)	Table 2.9	Rijnsoever et al. (2008)	Table 2.2
Gooroochurn & Hanley (2007)	Table 2.9	Rothaermel & Thursby (2005)	Table 2.2
Hong (2008)	Table 2.13	Sherwood & Covin (2008)	Table 2.2
Horng & Hsueh (2005)	Table 2.2	Siegel et al. (2003)	Table 2.2
Houghton, Smith, Hood (2009)	Table 2.12	Silipo (2008)	Table 2.9
Inzelt (2004)	Table 2.13	van de Vrande et al. (2009)	Table 2.9
Jiang & Li (2009)	Table 2.2	Veugelers & Cassiman (2005)	Table 2.2
Kasch & Dowling (2008)	Table 2.4	Wiklund & Shepherd (2009)	Table 2.10
Ke & Wei (2007)	Table 2.9	Wright et al. (2008)	Table 2.13
Kodama (2008)	Table 2.2	Ybarra & Turk (2009)	Table 2.12
Kwon (2009)	Table 2.12	Zheng et al. (2008)	Table 2.12
L´opez Iturriag & Mart´ın Cruz (2008)	Table 2.10		

Appendix 4 Studies of Resources and University-Industry Collaboration

Author (s)	Topic	Property-based Resource		Knowledge Resources			Organisational Resources			Relationship Resources			Technology Transfer Office	Other
		Physical Resources	Financial Resources	Basic Science Knowledge	Applied Science Knowledge	Human Capital	Alliance experience	Support and Reward	Institutional Structural	Social Networks	Trust	Commitment		
Acworth (2008)	(U) Knowledge Integration Community model of MIT							(U) Support mechanism, (U) Review processes & mechanism	(U) Organisation al structure				(U) Functional components	
Arvanitis et al. (2008)	(U) University industry knowledge transfer				(U) Orientation of applied research		(U) Experience							(U) Teaching obligations
Azagra-Caro et al. (2006)	(U) UIC R&D cooperation			(U) Dedication to R&D activities		(U) Faculty in technology/ & engineering (U)Senior (U)Gender		(U) University encourageme nt (U) Influence of UIC on faculty incentives	(U) Instruments of cooperation					(U) University age
Baba et al. (2009)	(F) Firms' R&D productivity					(U) Star / Pasteur/ Edison scientists								
Bagchi-Sen (2007)	(F) Commerciali zation of biotech firms	(U) University research facilities	(F) Venture capital			(U) University research scientists				(U) Proximity other biotech companies				Local availability of scientists, Local government assistance
Bayona Sàez et al. (2002)	(F) Firms cooperate with university		(F) Funding	(F) Undertake basic research						(F)Internatio nal knowledge networks				

(U)=University Resources, (F)=Firm Resources

Appendix 2 Studies of Resources and University-Industry Collaboration *(Continued)*

Author (s)	Topic	Property-based Resource		Knowledge Resources			Organisational Resources			Relationship Resources			Technology Transfer Office	Other
		Physical Resources	Financial Resources	Basic Science Knowledge	Applied Science Knowledge	Office	Alliance experience	Support and Reward	Institutional Structural	Social Networks	Trust	Commitment		
Bercovitz & Feldman (2007)	(F) Firms cooperate with university			(F) Exploratory activities (internal R&D strategies)					(F)Centralized internal R&D organizations					
Boardman & Ponomariov (2009)	(U) university researchers working with private companies		(U) Number of students funded (F) Industry grants	(U) Scientific values	(U) Age, (U)Minority status, (U)Gender	(U) Percentage of work time	(U) Number of collaborators			(U) Affiliation with research center				(U) Supported by government
Chang et al. (2006)	(U) Academic innovation (patent , licensing, incubation)				(U) Intellectual property managerial capability			(U) Entrepreneurial orientation of a university		(U) External industrial partnership				
Chen and Lin (2004)	(F) Inter-firm knowledge transfer performance			(F) Absorptive capacity (F) Explicitness of knowledge							(F) Trust			(F) Adjustment
Eun et al. (2006)	(U/F) University-run enter-prises			(F) Absorptive capacity									(U) Intermediary institutions	(U) Internal resources (U) University Propensity
Fischer & Varga (2003)	(U) R&D productivity		(U) R&D investment	(U) University research										
Foltz et al. (2003)	(U) Patent production					(U) Quality faculty			(U) Land grant infrastructure				(O) Patent-oriented TTO	(U) Dynamic feedback
Giuliani & Arza (2009)	(F) Knowledge diffusing			(F) Knowledge base (U) Department' Scientific quality		(F) Formal training and experience								

(U)=University Resources, (F)=Firm Resources

Appendix 4 Studies of Resources and University-Industry Collaboration *(Continued)*

Author (s)	Topic	Property-based Resource		Knowledge Resources			Organisational Resources			Relationship Resources			Technology Transfer Office	Other
		Physical Resources	Financial Resources	Basic Science Knowledge	Applied Science Knowledge	Office	Alliance experience	Support and Reward	Institutional Structural	Social Networks	Trust	Commitment		
Horng & Hsueh (2005)	(U) Alliance with firm							(U) Greater rewards					(O) TTO members marketing experience	
Kodama (2008)	(F) UIC technology transfer		(F) R&D expenditure											
Landry et al. (2006)	(U) Spin-offs	(U) University size (U) Research unit size	(F) Private Funding (F) Research partnership funding	(U)Publication (U)Research field (U) Novelty of research	(U)Research project that focus on user's need (U) IP Protection	(U) Personnel experience (U)Seniority (U)Teaching	(U) Organisational assets							
Laursen & Salter (2004)	(F) Cooperation with university		(F) Age (F) Size	(F) R&D intensity			(U) Practices	(U) Compensation (U) Rewards for faculty						(F) Openness
Leitch & Harrison (2005)	(U) University Spin-offs		(U) Finance	(U) Technology		(U) People		(U) Support						(U)Advice (U) Ownership
Li & Chen (2009)	(F) Resources and firm performance		(F)Finance (funding, Planning, cash flow, financial control)	(F) Technology (Research capability, manufacturing technology, protection of intellectual rights)					(F) Team (Structure of team)				(F) Team (CEO Capability)	(F) Marketing Capability
Lockett & Wright (2005)	(U) Spin-offs creation		(U) External IP Advice Expenditure		(U)Stock of technology to commercialize		(U) Experience of technology transfer	(U) Reward system that promotes commercialization					(U) Availability of TTO staff	(U) Business development capabilities

(U)=University Resources, (F)=Firm Resources

Appendix 4 Studies of Resources and University-Industry Collaboration *(Continually)*

Author (s)	Topic	Property-based Resource		Knowledge Resources			Organisational Resources			Relationship Resources			Technology Transfer Office	Other
		Physical Resources	Financial Resources	Basic Science Knowledge	Applied Science Knowledge	Office	Alliance experience	Support and Reward	Institutional Structural	Social Networks	Trust	Commitment		
Macho-Stadler et al. (2007)	(U) University licensing												(O) TTO Size	
McAdam et al. (2006)	(U/F) University incubators							(F) Business support		(F)Social support (entrepreneurial networks)				
Motohashi (2005)	(F) UIC	(F) Firm size												
Mueller (2006)	Economic growth		(U)Capital intensity (F)UIC (industrial grants per researcher)	(F) R&D in private industries (U) R&D in universities		(U) Labor		(U) Entrepreneurship (start-up rate)						Population density
Numprasertch & Igel (2005)	(U) Cooperation with industry			(U) Storage technologies							(U) Trust	(U) Communication		
Rothaermel & Thursby (2005)	(F) Incubator firm performance			(U) Citations to university journals	(U) University licenses/ Patent citations									(F) Absorptive capacity
O'Shea et al. (2005)	(U) university spin-off performance		(F)Industry-funded research (U)Universities R&D budge (G)federal funds	(U) Rating of university department			(U) Institutional resources (history of spinning out tech-based firms)						(U) Commercial resources (human resources of TTO)	(U) Commercial resources (presence of a university affiliated incubator)

(U)=University Resources, (F)=Firm Resources

Appendix 4 Studies of Resources and University-Industry Collaboration *(Continued)*

Author (s)	Topic	Property-based Resource		Knowledge Resources			Organisational Resources			Relationship Resources			Technology Transfer Office	Other
		Physical Resources	Financial Resources	Basic Science Knowledge	Applied Science Knowledge	Office	Alliance experience	Support and Reward	Institutional Structural	Social Networks	Trust	Commitment		
O'Shea et al. (2007)	(U) Academic entrepreneurship of MIT			(U) MIT's science and engineering resource		(U) Quality of research faculty		(U) Culture to encourage entrepreneurship					(U) Supporting mechanisms and policies (TTO)	
Østergaard (2008)	(F) Knowledge flows					(F)Employees educated at the local university				(F)Mobility (F) Projects with other institute	(F) Trust (F) Familiarity			
Owen-Smith & Powell (2003)	(U) Patent citation counts			(U)Scientific capacity (life science articles, medical articles)			(U)Technology transfer experience			(U) Network				
Powers & McDougall (2005)	(U) University commercialization activities		(F)Industry research funding (U)Venture capita		(U) University patents	(U) Faculty quality		(U) University patent importance					(O) TTO age	
Price et al. (2008)	(U) University technology commercialization			(U) Published peer-reviewed articles		(U) Researcher has previous patents/ copyrights	(U) Experience in technology transfer						(U) Experience with commercial partners	
Segarra-Blasco & Arauzo-Carod (2008)	(F) Sources of innovation	(F) Firm size	(F) Public funding (F) R&D intensity	(F)Absorptive capacity (F)Intramural R&D activities						(F) Belong to a group				(F) Perform product and process Innovation
Siegel et al. (2003a)	(U) Commercial knowledge transferring to firms								(O) Bureaucratic inflexibility				(O) Management effectiveness (O) TTO reward systems	(U) Culture clashes

(U)=University Resources, (F)=Firm Resources

Appendix 4 Studies of Resources and University-Industry Collaboration *(Continued)*

Author (s)	Topic	Property-based Resource		Knowledge Resources			Organisational Resources			Relationship Resources			Technology Transfer Office	Other
		Physical Resources	Financial Resources	Basic Science Knowledge	Applied Science Knowledge	Office	Alliance experience	Support and Reward	Institutional Structural	Social Networks	Trust	Commitment	Office	
Siegel et al. (2003b)	(U) Commercial knowledge transferring to firms			(U) Explicitness of knowledge				(U) Compensation (U) Rewards for faculty					(O) TTO staffing	(U) Land grant infrastructure
Sherwood & Covin (2008)	(F) knowledge acquisition success			(F) Technology Familiarity			(F) Technology agreements Experience		(F) Formal collaboration teams					(F) Communications between experts
Tether & Tajar (2008)	(F)UIC cooperation			(F) Absorptive capacity						(F)Social capital & networking capabilities		(F)Deeper commitments to innovation		(F)Firm's openness
Stuart et al. (2007)	(F) Knowledge sources									(F) Social networks	(F) Relationship (trust, communication, coordination, shared value)			
van Rijnsoever et al. (2008)	(U) Interaction with industry			(U) Dynamic of the scientific field		(U)Work experience								(U) Global innovativeness
Veugelers & Cassiman (2005)	(F) Linkage with university		(F) Size (F) Cost	(F) Internal know-how capabilities (F) R&D capacity (absorptive capacity)						(F) Firms with foreign headquarters				(F) Risk
Wright et al. (2006)	(U)University spin(-offs		(F)Venture capital											
Wu (2007)	(U) Link with industry													(U) Universities autonomy
Yusuf (2008)	(U) University knowledge transfer		(F) Financial intermediary		(F) IP management practices								(O) Specialized intermediary	(U) Institutional intermediary (e.g public agency)

(U)=University Resources, (F)=Firm Resources

Appendix 5 Literature of University-Industry Activities

Author	Knowledge transfer, interaction, and collaboration of university and industry
Arvanitis et al. (2008)	**1.Informal informational contacts** · Informal contacts (phone, email) · Conferences, exhibitions, workshops · Academic publications of business sector . **2.Activities related to the use of technical facilities.** · Joint laboratories · Technical facilities or research centres at business sector R&D department. **3. Educational activities.** · Contacts with graduates employed in the business sector · Contacts with former staff employed in the business sector · Student participation in corporate R&D projects · Thesis projects in collaboration with firms · Doctoral projects in collaboration with firms · Business sector scientists in own R&D projects · Joint teaching courses or programmes · Teaching assignments for business sector staff · Courses or programmes of institute by business sector scientists . **4.Research activities** · Research projects in collaboration. · Longer term research contracts. · Research consortiums . **5.Consulting** · Expertise's/reports for the business sector · Consulting for the business sector .
Bekkers & Bodas Freitas (2008)	**1. scientific output, informal contacts and students;** · Scientific publications in (refereed) journals or books · Other publications, including professional publications and reports · Participation in conferences and workshops · Personal (informal) contacts · University graduates as employees (B.Sc. or M.Sc. level, Ph.D. level) · Students working as trainees **2.labour mobility;** · Flow of university staff members to industry positions (exc. Ph.D. graduates) · Staff holding positions in both a university and a business · Temporary staff exchange (e.g. staff mobility programmes **3.collaborative and contract research;** · Joint R&D projects in the context of EU Framework Programmes · Joint R&D projects (except those in the context of EU Framework Programmes) · Contract research (excl. Ph.D. projects) · Financing of Ph.D. projects · Consultancy by university staff members **4.contacts via alumni or professional organizations;** · Personal contacts via membership of professional organisations · Personal contacts via alumni organisations **5.specific organised activities;** · Contract-based in-business education and training delivered by universities · University spin-offs (as a source of knowledge) · Specific knowledge transfer activities organised by the university's TTO · Sharing facilities (e.g. laboratories, equipment, housing) with universities **6. patents and licensing** · Patent texts, as found in the patent office or in patent databases · icenses of university-held patents and 'know-how' licenses
Boardman & Ponomariov (2009)	· Persons from a private company have asked for information about my research and I have provided it · I contacted persons in industry asking about their research · I served as a formal paid consultant to an industrial firm · I worked at a company with which I am owner, partner, or employee · I worked directly with industry personnel in work that resulted in a patent or copyright · I worked directly with industry personnel in an effort to transfer or commercialize technology or applied research · I helped place graduate students or post-docs in industry jobs · I co-authored a paper with industry personnel that has been published in a journal or refereed proceedings

Appendix 5 Literature of University-Industry Activities *(Continued)*

Author	Knowledge transfer, interaction, and collaboration of university and industry
Cohen et al. (1998)	· Publications, · Public meetings and conferences, · Informal and personal information contracts, · Consulting contracts, · Patent, · Licenses, · Joint ventures, · Contract research, · Consulting, · Hires and personal exchange
D'Este & Patel (2007)	**1.Meetings and conferences** · Attendance at Industry sponsored meetings · Attendance at Conferences with industry and university participation **2.Consultancy and contract research** · Consultancy work (commissioned by industry, non involving original research) · Contract research agreements (commissioned by industry and undertaken only by university researchers) **3.Creation of physical facilities** · Setting up spin-off companies · Creation of physical facilities with industry funding (including campus laboratories, incubators and cooperative research centres) **4.Training** · Postgraduate training in company (e.g. joint supervision of PhDs) · Training company employees (through course enrolment or personnel exchanges) **5.Joint research** Joint Research agreements (involving research undertaken by both parties)
Inzelt (2004)	**Interaction Between individuals** · Ad hoc consultations of firm employees at universities · Lectures of firm employees held at universities · Lectures of faculty members held at firms · Regular (informal) discussions between faculty members and firm employees on the meetings of professional associations, at conferences, and seminars · Buying university research results (patents) ad hoc basis **Individual/institutional interaction** · Employing faculty members as regular consultants Individual/institutional · Coaching of firm employees by university researchers · Training of firm employees by university professors · Joint publications by university professors and firm employees · Joint supervision of Ph.D. and master theses by university and firm members · Joint IPRs by university professors and firm employees **Institutional interaction** · Access to special equipment of firm/university with or without assistance of owner's organisations · Invest into university's facilitates · Regular acquiring university research · Formal R&D co-operations such as contract research · Formal R&D co-operations such as joint research projects **Knowledge flows** · Knowledge flows through permanent or temporary mobility from universities to firms · Knowledge flows through spin-off formations of new enterprises
Lee & Win (2004)	· Collegial interchange, conference, and publication · Consultancy and technical services provision · Science park, research park, technology park or incubators · Joint venture of R&D · Licensing · Contract research · Cooperative R&D agreement · Exchange program · Training
Polt et al. (2001)	· Informal contacts · Graduate Mobility and Training · Consulting · Research Mobility · ContractResearch · Joint Research · Spin-offs/Strat-up
Wright et al. (2008)	· spin-off activities · Licensing activities · Contract Research · Consulting · Graduate and Research Mobility